USAF
PRAM PROGRAM
FINAL REPORT

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PRAM PROJECT FINAL REPORT

CARBON DIOXIDE PELLET BLASTING AUGMENTED XENON FLASHLAMP
COATINGS REMOVAL DESIGN AND PROTOTYPE DEMONSTRATION PROJECT

Warner Robins Air Logistics Center
Office of the Chief Engineer
WR-ALC/CN

30 March 1993

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1. EXECUTIVE SUMMARY

Air Force aircraft exterior coatings are removed every 4 to 8 years to facilitate various maintenance functions. One of the largest generators of hazardous waste in the Air Force has typically been the paint removal operations. Historically, the Air Force has used extremely harsh chemicals to remove the advanced coatings used on modern aircraft. Large volumes of hazardous waste (e.g., approximately 10,000 gallons for the F-15 aircraft) are produced with each aircraft that is stripped. In addition, the chemicals are not compatible with composite substrates.

In May 1990, WR-ALC began evaluating CO_2 pellet blasting to remove surface coatings. WR-ALC successfully improved the CO_2 pellet blasting process for application to aircraft metals. However, the process is too aggressive for application to composite substrates. In mid-1990, McDonnell Douglas Aerospace, Cold Jet, Inc., and Maxwell Laboratories, Inc., jointly developed the synergistic CO_2 augmented xenon flashlamp approach. This involves the flashlamp technology to remove surface coatings while the CO_2 keeps the lamp clean, removes the resulting soot, and provides substrate cooling.

The Productivity, Reliability, Availability, and Maintainability (PRAM) project prototype CO_2 augmented flashlamp system developed under this program consists of a stripping head, a high voltage power supply/controller, a government furnished CO_2 pellet blasting system, and a contractor supplied effluent capture system.

Test data was generated for both the PRAM funded 6-inch demonstration and validation prototype and a contractor funded 12-inch prototype production system. For the PRAM 6-inch demonstration/validation system, strip rates were 0.3 sq ft/min to remove 5 mils of coating to bare metal and 1.0 to 1.5 sq ft/min to remove 4 mils of coating, leaving the primer on metal or composite substrates. For the "next generation" contractor funded 12-inch flashlamp, strip rates were 1.0 to 2.5 sq ft/min to remove 5 mils of coating to bare metal and 2.5 to 4.0 sq ft/min to remove 4 mils of coating, leaving the primer on the metal or composite substrates. Test data generated to date have indicated that the CO_2 flashlamp process produces no changes in the properties of aircraft materials.

An $850K follow-on effort will install a production prototype system for stripping the composite areas of the F-15 aircraft. If the production system were to be implemented for complete stripping of a fighter-sized aircraft in an existing hangar, total implementation cost is estimated to be $5,236,000 including robot, flashlamp/CO_2 systems, ventilation, compressors, etc.

PRAM investment to date is $507K. The Navy also provided $350K for materials testing. An additional $850K investment is required for production prototyping. The life-cycle savings of this process are estimated at $72M based on full implementation on an F-15-sized aircraft and compared to chemical depaint process over a 15-year estimated equipment life. Return on investment is estimated at 9.37 to 1.

Other benefits to be derived from the process include reduction in hazardous waste output, reduction in aircraft flow time, increased capability to strip composite materials, and the capability to strip all materials with less damage.

2. INTRODUCTION

The Air Force Corrosion Program Office, WR-ALC/CNC, is responsible for investigating new aircraft coatings removal processes that can reduce overall cost, hazardous waste production, and potential aircraft damage, while increasing worker and aircraft safety. McDonnell Douglas Aircraft Corporation briefed the PRAM organization on the merits of a CO_2 pellet blasting augmented xenon flashlamp system for aircraft coatings removal in Jan 91. While there are several new alternative coatings removal processes currently being evaluated by the Air Force, the CO_2 augmented flashlamp technology has the potential to eliminate or greatly reduce hazardous waste generated in coatings removal operations and to greatly reduce the cost of those operations. The process also has the potential to be all but benign to all aircraft materials. These beneficial characteristics have not been demonstrated by any other coatings removal technology to date. The level of damage possible with currently authorized coatings removal technologies (chemical depaint and plastic media blasting) has been evaluated as too high for application to some critical aircraft metals and composite materials. Composite materials, in particular, are lacking an acceptable, nondamaging coatings removal process. The CO_2 augmented flashlamp technology has the potential to fill this technology void.

The Air Force Corrosion Program Office agreed to manage this initial effort to design, construct, and test a demonstration/validation prototype of the CO_2 augmented flashlamp technology. Dr William F. White, Warner Robins Air Logistics Center's Chief Engineer, was the overall project director with Mr Randall B. Ivey as project engineer/program manager.

The project was accomplished in six phases: Phase 1, prototype design and construction; Phase 2, process optimization; Phase 3, effluent capture system concept development; Phase 4, optimization continuation/limited materials testing; Phase 5, prototype robotic interface; and Phase 6, WR-ALC demonstration.

The prototype system built under this project consists of an integrated stripping head, high voltage power supply/controller, and a WR-ALC supplied CO_2 pellet blasting system. The CO_2 augmented flashlamp system is temporarily integrated to a robot in the F-15 Robotic Depaint Booth located in Bay 4, Building 137, Robins AFB GA. The contractor also developed and prototyped an effluent capture system using contractor funds. This capture system is currently on loan to WR-ALC and integrated with the CO_2 augmented flashlamp system.

The prototype system has demonstrated the capability to strip all aircraft coatings tested to date. The flashlamp vaporizes coatings by transferring energy to the coating surface via high intensity light. The amount of energy applied to the surface can be varied by changing the amount of power going to the lamp. The coatings removal rate is directly proportional to the amount of energy applied to the surface. The CO_2 pellets provide surface cooling and a cleaning action to remove the vaporization products. The stripping process is very controllable, allowing the user to remove various thicknesses of coating by changing the process parameters.

3. TECHNICAL INVESTIGATION

Statement of the Problem

Air Force aircraft exterior coatings are removed every 4 to 8 years to facilitate various maintenance functions. First, the top coat has a mechanical life expectancy in that range of time. The top coat suffers from environmental effects, flight wear, and from maintenance personnel accessing various aircraft hatches and panels. Second, Air Force aircraft are maintained to a high degree of professional appearance which is facilitated through numerous complete overcoatings of the aircraft. The additional layers of paint add weight to the aircraft and must be removed periodically. Third, complete coatings removal may be required to allow nondestructive inspection of the aircraft surface or to allow other types of maintenance activities to be performed on aircraft surfaces.

One of the largest generators of hazardous waste in the Air Force has typically been the paint removal operations. Historically, the Air Force has used extremely harsh chemicals to remove the advanced coatings used on modern aircraft. The Air Force, in general, and the Warner Robins Air Logistics Center, in particular, have been striving toward the elimination of chemical paint stripping because of the high cost required to make this process conform to increasingly strict environmental and health requirements. Large volumes of hazardous waste (e.g., approximately 10,000 gallons for the F-15 aircraft) are produced with each aircraft that is stripped. Chemical strippers also have a methylene chloride base which the Occupational Safety and Health Administration (OSHA) has listed as a known carcinogen. OSHA has limited worker exposure to levels that are not achievable in an aircraft stripping environment. In addition, methylene chloride may soon be classified as a volatile organic compound (VOC), further restricting its use.

In the mid-1980s, plastic media blasting looked like a very promising solution toward reducing much of this problem. However, this process generates a sizable volume (e.g., approximately 3,000 pounds per F-15 aircraft) of dry hazardous waste. In addition, man-hour intensive operations to prevent/remove ingressed media are also required with plastic media blasting. Even with these drawbacks, plastic media represents a tremendous improvement over chemical paint stripping processes.

The chemical and plastic media blasting processes have a wide variety of application. However, the chemicals are not compatible with composite substrates, and plastic media is too abrasive for many composite applications. The CO_2 augmented flashlamp process was evaluated and selected as a candidate to reduce these environmental hazards and the cost of depaint operations and to provide an acceptable depaint process for both composites and metals.

Investigation and Findings

In 1987, a flashlamp depainting PRAM project for SM-ALC was completed. While the flashlamp alone is capable of removing surface coatings, this early system had some drawbacks that affected its application. These included lamp reliability, cumbersome and awkward handling, soot resulting from paint ablation, substrate heating, and the lack of a structural mechanical properties degradation evaluation.

In May 1990, WR-ALC began evaluating CO_2 pellet blasting to remove surface coatings. This program was designed to replace chemical and solid media blasting processes. WR-ALC successfully improved the CO_2 pellet blasting process for application to aircraft metals. However, the process is too aggressive for application to composite substrates. In mid-1990, McDonnell Douglas Aerospace, Cold Jet, Inc., and Maxwell Laboratories, Inc., jointly developed the synergistic CO_2 augmented xenon flashlamp approach. This involves the flashlamp technology to remove surface coatings, while the CO_2 keeps the lamp clean, removes the resulting soot, and provides substrate cooling. The CO_2 augmented flashlamp system was thought to be almost benign to the aircraft substrates because the system vaporizes the coatings from the surface. The potential environmental impact was also evaluated as low because the stripping process/material does not add to the waste stream, and the hazardous waste (the removed coating) is reduced in volume because it is vaporized. McDonnell Douglas developed a process comparison matrix (Figure 1) to compare various paint stripping processes and found that CO_2 augmented flashlamp has a tremendous potential compared to other methods of coatings removal.

McDonnell Douglas Aircraft Corporation briefed the PRAM organization on the merits of a CO_2 pellet blast augmented xenon flashlamp system for aircraft coatings removal in Jan 91. The Air Force Corrosion Program Office agreed to manage this initial effort to design, construct, and test a demonstration/validation prototype of the CO_2 augmented flashlamp technology. Dr William F. White, Warner Robins Air Logistics Center's Chief Engineer, was the overall project director with Mr Randall B. Ivey as project engineer/program manager. This activity led to the development of the first CO_2 augmented flashlamp prototype.

Technical Approach

System Description

The PRAM project prototype CO_2 augmented flashlamp system developed under this program consists of a stripping head, a high voltage power supply/controller, a government furnished CO_2 pellet blasting system, and a contractor supplied effluent capture system.

The prototype stripping head consists of a flashlamp module that contains the 6-inch lamp, reflector, and water cooling system. The bracketry for mounting the 6-inch wide CO_2 nozzle, motion and proximity sensors, and the effluent capture shroud are attached to the flashlamp module, resulting in an integrated unit. Figure 2 shows the final installation of the system on the rear robot for the F-15 robotic depaint cell, Building 137, Robins AFB GA. A more detailed picture of the system is shown in Figure 3.

The high voltage power supply/controller provides the energy to operate the flashlamp. Computer control is provided for flashlamp energy levels and pulse rates. The deionized water cooling reservoir, pumps, and filters are also located within the cabinet seen in Figure 4.

The CO_2 pellet blasting system, Cold Jet Model 65-200 (Figure 5), manufactures pellets from liquid CO_2 and provides a means of delivery and control to the nozzle of the stripping head.

Process Description

The pulsed light energy source consists of a quartz tube filled with xenon gas that, when electrically energized, emits a brilliant flash of broad spectrum light. As the paint absorbs the photon energy, its temperature rapidly rises to the point at which a thin layer (approximately 1 mil per pulse) is ablated and released from the surface. In normal stripping operations, the light is flashed four times each second. As the paint or coating is ablated, the residue is simultaneously removed from the surface by the low pressure (140 psi) CO_2 pellet stream.

CO_2 gas (source of the dry ice pellets) is a by-product of many other industrial processes. If left uncollected, the gas is vented to the atmosphere. The gas is collected, purified, and converted to a liquid state. The liquefied CO_2 is commercially available world wide. In this process, the Cold Jet equipment converts the liquid CO_2 into solid dry ice pellets and delivers them via a low pressure air stream to the nozzle. Upon impact, the pellets sublime to a gaseous state.

The synergism achieved with the CO_2 augmented flashlamp coatings removal process results in an excellent method for nondamaging coatings removal. As quickly as the pulsed light energy ablates the paint, the continuous flow of CO_2 pellets sweeps away the residue. The heating effect of the pulsed light energy is offset by the cooling effect of the CO_2 flow. During the stripping process, the continuous flow of CO_2 pellets also maintains the cleanliness of the flashlamp window, ensuring maximum transmission of photon energy to the surface. The CO_2 rich environment at the point of ablation also provides an atmosphere that will not support combustion.

Process Control

A major advantage of the CO_2 augmented flashlamp system coatings removal process over current and other developmental processes is the degree of control achievable. By varying operating parameters, such as pulsed light energy density, pulse rate, stripping head rate of travel and stand-off, and CO_2 delivery pressure and nozzle angle, varying degrees of paint removal can be achieved. These include complete coatings removal (top coat and primer) to bare metal, removal of selected layers of topcoats (leaving the primer intact and undamaged), and chemically free cleaning of the surfaces using only the CO_2 pellet stream. This selective stripping capability is in stark contrast to all chemical and most liquid/solid media impingement processes which are limited to removing the entire finish system to the substrate. Selective stripping is particularly attractive for composite substrates, since leaving the primer precludes any subsequent damage. The increased use of composites in aircraft construction has introduced a unique set of problems relating to coatings removal. Many chemical strippers attack composite resins as they destroy the paint and primer molecular bonds. Also, composites are particularly susceptible to damage from high velocity solid or liquid media. By using the control options available to remove only the topcoats and leave the primer intact, the CO_2 augmented flashlamp provides a capability which is impossible to attain with most other coatings removal processes.

Reliability and Maintainability

Manufacturers of the components that comprise the CO_2 augmented flashlamp system were selected partly for their attention to providing a high degree of system reliability and maintainability. McDonnell Douglas Aerospace (MDA), as prime contractor, Maxwell Laboratories, and Cold Jet are familiar with and have designed and built their respective equipment with high reliability and maintainability as a prime consideration.

Because of the prototype status of the flashlamp stripping head and power supply, no historical database exists. MDA is monitoring and collecting R&M data for further analysis. Predicted service life of the pulsed power system is 20,000 operating hours. Known consumables include the following:

Xenon lamps

- Lamp Life - 8 hours
- Lamp Cost - $250-$300 each
- Lamp Replacement Time - 15 minutes

The Cold Jet unit has been commercially available since 1990. Documented Reliability and Maintainability data include the following:

- Design Service Life - 10,000 Hours
- Current Mean Time Between Failure - 1000 Hours
- Current Mean Time To Repair - 4 Hours (one technician)
- Scheduled Maintenance Interval - 500 Hours (inspect, change filters, lubrication)

Materials Testing

Section 4.0, Mechanical Properties Tests, of the attached contractor's final report (Appendix 1) contains information on the test specimen, program test procedures, and test results to date. Additional test data for metal test specimen will be available by 30 Jun 93 and will be provided as an addendum to the final report. A review of the test data received to date shows that no damage is induced on the composite parts if the last layer of primer is left intact. Attempts to remove all primer will inevitably cause the removal of some resin. This resin loss leads to an average degradation in failure stress of 16.6 percent.

Strip Rates

Strip rate data is included in the mechanical test section (Table 2, page 11 of Appendix 1) of the final report. Data are presented for both the PRAM funded 6-inch demonstration/validation prototype and a contractor funded 12-inch prototype production system. For the PRAM 6-inch demonstration/validation system, strip rates were 0.3 sq ft/min to remove 5 mils of coating to bare metal and 1.0 to 1.5 sq ft/min to remove 4 mils of coating, leaving the primer on metal or composite substrates.

For the "next generation" contractor funded 12-inch prototype production system, strip rates were 1.0 to 2.5 sq ft/min (depending on the type of paint) to remove 5 mils of coating to bare metal and 2.5 to 4.0 sq ft/min (depending

on the type of paint) to remove 4 mils of coating, leaving the primer on the metal or composite substrates.

Occupational Health

Section 5.0, Occupational Health Hazard Assessment Report, of the attached contractor's final report (Appendix 1) contains a detailed analysis of the effluent that is produced from CO_2 augmented flashlamp stripping operations. Phase 3 of this project required the contractor to analyze the effluent and provide an initial design concept for an effluent capture system. The contractor went beyond the contract requirements and provided (at the contractor's expense) a prototype effluent capture system which proved capable of containing the effluent. While this prototype did not contain the recommended activated carbon absorption bed, it did show proof of concept. This section of the report details the known requirements for an effluent capture system including the carbon absorption system. A complete prototype system, including the carbon absorption bed, would have to be evaluated to ensure complete hazard abatement.

Safety

Section 6, Safety, of the attached contractor's final report (Appendix 1) provides an analysis of worker safety related issues. Hearing and eye protection are required when operating the CO_2 augmented flashlamp system.

Process Evaluation

The prototype CO_2 augmented flashlamp system was delivered to WR-ALC on 24 Sep 92 and integrated with the rear robot in F-15 Robot Depaint Cell, Bldg 137, Bay 4. Testing, evaluation, and demonstrations of the system are continuing as of the date of this report. The CO_2 augmented flashlamp system has been shown to be an excellent tool for controllable paint removal. The following results have been obtained through testing in a production environment.

Stand-off Distance. The prototype system has a relatively small focal point which requires that the stand-off distance be maintained to ± 0.125 of an inch in order to achieve a uniform strip rate. The robots currently in use in the F-15 Robotic Depaint Cell cannot provide the required accuracy to provide a uniform strip of the surface. This problem can be solved by the application of an end-effector compliance device which will maintain the required stand-off distance with extreme accuracy. The contractor-funded production prototype system currently undergoing tests at Maxwell Labs has an expanded focal point envelope, somewhat reducing the problem. However, even this system would have improved quality and repeatability with the compliance device.

Coating Thickness. The CO_2 augmented flashlamp system can be adjusted to strip any thickness of paint by adjusting the power to the lamp, the frequency of flashing, and the head traversing rate. Typical measurements of an F-15 aircraft have found between 5 and 15 mils of paint on metal surfaces and between 12 and 25 mils of paint on composite substrates. The composites tend to have more paint build-up because there is no current production system to completely depaint these surfaces, whereas the metal surfaces are completely depainted every 4 to 6 years. The paint thickness on a given aircraft will

tend to vary from one area to the next by as much as 10 mils. The CO_2 augmented flashlamp has not been shown to be damaging to metal surfaces if they are "overprocessed." For this reason, the system can be set to run as if all metal surfaces have the greatest thickness of paint on them. With these parameters, the flashlamp would be needlessly slow over the areas of the plane that have thin coatings. Overprocessing of composites will cause a degradation in the material's mechanical properties. For this reason, composite stripping with the CO_2 augmented flashlamp system requires active control to prevent overprocessing. Higher productivity on metals and safety on composites can be achieved with the addition of a sensor to detect when the coatings are removed. This information will then be input into the robot and flashlamp control loops.

Conclusions and Recommendations

The CO_2 augmented xenon flashlamp system demonstrated under this program has been shown to be viable for aircraft coatings removal. Initial data from the materials characterization test show the process is nondamaging to both metals and composites if used correctly. The contractor funded prototype production flashlamp system has shown extremely high strip rates for both composites and metal substrates on a variety of Air Force coatings systems.

In order to fully utilize the capabilities of the CO_2 augmented flashlamp in a production environment, three accessories for the technology must be developed and integrated with the flashlamp system. These accessories are as follows:

a. Effluent capture system. The demonstration/validation prototype included a contractor funded, first generation effluent capture system which was not effective in removing the VOC component of the gases evolved during the stripping operations. An improved effluent capture system to eliminate the VOCs should be developed and integrated with the flashlamp technology.

b. Surface profile compliance system. The initial flashlamp tests have shown that the productivity and repeatability of the system is a function of the robot's ability to maintain consistent distances to the substrate being stripped. The robots currently used or being designed for aircraft depainting do not achieve the required accuracy. A surface profile compliance system should be developed to work in harmony with any robot as a part of the flashlamp system end effector. A compliance system will allow precise control of the flashlamp stand-off distance and allow for easier robot programming.

c. Substrate detection sensor. Tests with the demonstration/validation system on aircraft surfaces have shown that a substrate detection sensor is required to maximize productivity and prevent substrate damage. A colorimeter-based sensor should be designed to detect the substrate primer interface. Colorimeter-based sensor technology has been suggested as the best candidate technology, limiting risk and cost.

In addition, the demonstration/validation prototype system has shown strip rates of 1 square foot per minute on 5 mil thick paint. Operational aircraft composites have up to 25 mils of paint which will significantly reduce strip rate. The prime contractor has developed a follow-on prototype production system with a 300 percent improvement in strip rate. It is recommended that any production CO_2 augmented flashlamp incorporate the upgraded 12-inch system.

4. LESSONS LEARNED

DATA ITEMS FOR DELIVERY UNDER PROTOTYPE DEVELOPMENT EFFORTS

a. Upon review of the statement of work for this project, Data Item Management personnel had recommended delivery of level-three drawings of the entire system. This recommendation was based on the fact that a prototype system was being developed using Air Force funding. Level-three drawings and associated documentation are relatively expensive and were not funded for this program.

b. A more accurate statement of the demonstration/validation nature of the prototype was provided to Data Item Management personnel. The fact that this was a one-time project that was seen as an evolutionary step in the progress of the technology, that elements of the design were proprietary information predating the contract, and that there was no intent to buy future systems in this demonstration configuration allowed us to eliminate the requirement for level-three drawings on 95 percent of the equipment to be delivered.

c. A lesson learned was the need to ensure that all personnel in the contracting process are fully aware of the current and future intent of prototype development programs. In this case, the delivery of level-three drawings would have almost doubled the cost of the contract. In addition, the Air Force would receive no additional benefit from the data initially identified for delivery.

5. IMPLEMENTATION

Follow-on implementation will require the development of the prototype production 12-inch system outlined in the Conclusions and Recommendations section of this final report. If funded, this first production system will be integrated with the rear robot of the Warner Robins F-15 Robotic Depaint Cell, Bay 4, Bldg 137. This first implementation will validate system use in a production environment and validate operational cost of using the system in a production environment. OC-ALC, SA-ALC, SM-ALC, OO-ALC, Navy, Army, commercial airlines, and airframe manufacturers have all shown extreme interest in potentially using this system. The F-15 System Program Office has continued its support for the system and would like to see the production prototype developed and installed in the F-15 Robotic Depaint Booth.

Approach

Implementation is not possible without the development and operational testing of the production prototype system. Funding has been requested through the Technology Transition Office to support the development, installation, and testing of the prototype production system. Future implementation of the system will be funded through 3080 funds.

Status

Awaiting funding status.

Validation of Savings

A detailed cost comparison matrix (Appendix 2) has been developed using engineering estimates of the production prototype system's performance in a production environment. These estimates are based on laboratory tests with a 12-inch Maxwell Laboratories' system on test panels coated with representative Air Force coating systems. The mathematical model includes performance degradation factors consistent with the transfer of depaint processes from the laboratory to production environment. Column DP of this matrix is a payback period (in years) for various processes when comparing the processes to the baseline of chemical depainting of aircraft. Total savings of the process can be derived by subtracting the cost of stripping using the flashlamp from the cost of stripping using chemical depaint. This matrix will be updated with actual production data after the installation of the prototype production system is installed.

Schedule

No schedule can be projected until funding is received to develop and install the prototype production system. The contractor has indicated that production systems can be available shortly after completion of that follow-on effort. The follow-on project to install the prototype production system is estimated to be a 9-month project once on contract. Implementation for other weapon systems is possible within 12 months of the completion of the prototype production system. No milestone chart is attached.

6. ECONOMIC SUMMARY

The initial $490,000 in PRAM funds was used to design, build, and test a demonstration and validation 6-inch prototype of the CO_2 augmented flashlamp system. An additional $17,091 was received from PRAM to provide local robotic engineering support. An additional $350,000 was provided by Naval Aviation Depot (NADEP) Jacksonville to fund a full materials characterization study. WR-ALC has provided support in terms of manpower, facilities, and equipment for this project. The funding breakout is as follows:

PRAM Project Cost: $507,091

a. Subcontract to Maxwell Labs and Cold Jet for flashlamp/CO_2 design and prototype	$260,000
b. Prime Contractor, McDonnell Douglas for integration and project support	130,000
c. Test and Evaluation	70,000
d. Robot integration and demonstration	20,000
e. Travel	10,000
f. Robot integration support from MERC	17,091

PRAM investment to date = $507,091
Navy investment to date = $350,000
Additional investment required for production prototyping = $ 850,000

Total investment to bring technology to production maturity = sum of the three above = $1,707,091.

Based on the best available data, estimate life of the production capable system will be 15 years. The life-cycle savings of this process based on full implementation on an F-15-sized aircraft and compared to chemical depaint processes are as follows:

Implementation Cost. For the purpose of this report, the cost to implement a CO_2 augmented flashlamp in an existing facility will be used. The implementation cost will be based on one robot and flashlamp system which will be adequate to handle the required flow (100 F-15s per year) of aircraft. The robot design/cost is similar to the Safari robot currently being used in the F-15 Robotic Paint Facility, Bay 5, Bldg 137, Robins AFB GA. The Safari robot manufacturer has indicated the weight of this system is within the design constraints of that robot. Please note that the implementation costs for this project could be reduced substantially (approximately $1,500,000) if the manipulators being designed under a separate Technology Transition Office (TTO) project were utilized. Total implementation cost is estimated to be $5,236,000 including robot, flashlamp/CO_2 systems, ventilation, compressors, etc.

Useful Life Savings (ULS) - The useful life savings of this equipment is estimated over a 15-year period. The ULS for this project is calculated as the difference between current chemical stripping cost and robot assisted CO_2 augmented flashlamp.

Cost to chemically depaint 100 F-15s per year = $5,606,025 (relative estimate) per appendix 2.

Cost to flashlamp depaint 100 F-15s per year = $808,735 (relative estimate) per appendix 2.

Cost savings per year = $5,606,025 - $808,735 = $4,797,690 per year.

Cost savings for useful life = $4,797,690 X 15 = $71,965,350.

Appendix 2 to this project plan contains the database which was used to compute the cost comparison. The information in the database was obtained from actual production information or test data, where available. Data that were not available were estimated based on knowledge of the processes.

Return on Investment (ROI)

$$\text{ROI} = \frac{\$71{,}965{,}350 - (\$1{,}707{,}091 + \$5{,}236{,}000)}{(\$1{,}707{,}091 + \$5{,}236{,}000)} = 9.37$$

Other benefits to be derived from the process include reduction in hazardous waste output, reduction in aircraft flow time, increased capability to strip composite materials, and the capability to strip all materials with less damage.

7. APPROVAL AND COORDINATION

OFFICE SYMBOL	SIGNATURE	DATE
SES	[illegible]	25 May 93
CNC	[illegible]	14 may 93
CNC	Jay Freedman	14 May 93
CNT (PRAM)	[illegible]	24 May 93
CNT	[illegible]	7 May 93
CN	[illegible]	8 May 93

8. APPENDICES

MDC 92B0479

Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Prototype Development and Evaluation Program

David W. Breihan

McDonnell Douglas Corporation

1992

Department of The Air Force
Warner Robins Air Logistics Center

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MDC 92B0479

Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Prototype Development and Evaluation Program Final Report

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Prepared for
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Abstract

Increasingly stringent environmental regulations controlling the use and disposal of hazardous and toxic materials and increasing concerns over personnel safety and aging airframe structural integrity in an era of rapidly escalating costs are the issues which lead the McDonnell Douglas Corp., Cold Jet, Inc., and Maxwell Laboratories, Inc. team toward development of an environmentally safe and operator friendly alternative to chemical, solid, and liquid media paint stripping. A prototype development and evaluation program was successfully completed for the United States Air Force Producibility, Reliability, Availability, and Maintainability Office. The McDonnell Douglas, Cold Jet, and Maxwell team has taken a holistic approach to development of a paint removal technology which employs the synergy of pulsed light energy, low pressure dry ice particle stream, and total effluent capture. This approach significantly reduces aircraft paint stripping maintenance manhours and downtime, eliminates operating personnel exposure to hazardous and toxic chemicals, and it causes no damage to airframe structures. Of particular importance is the fact that the synergism of pulsed light energy and low pressure dry ice particle stream used for paint stripping is completely safe to composite subtrates when correctly applied to those surfaces.

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1.0 INTRODUCTION.

1.1 Objective -

The Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Prototype Development and Evaluation Program was an engineering study to design, prototype, test, and demonstrate pulsed light energy/CO_2 aircraft coatings removal proof-of-concept. The process is designed to safely and economically remove aircraft coatings without the use of hazardous chemicals or potentially damaging impingement media. Additionally, a major goal was to significantly reduce the amount of hazardous waste generated by the aircraft paint stripping process.

The project was accomplished in six (6) phases: phase 1, prototype design and construction, phase 2, process optimization and effluent analysis, phase 3, effluent capture system concept development, phase 4, optimization continuation, phase 5, prototype robotic interface, and phase 6, WR-ALC demonstration.

1.2 Historical Background -

In 1987 a flashlamp depainting PRAM project for SM-ALC was completed. While the flashlamp alone is capable of removing surface coatings, this early system had some drawbacks that affected its application. These included lamp reliability, cumbersome and awkward handling, soot resulting from paint ablation, substrate heating, and the lack of a structural mechanical properties degradation evaluation.

In mid 1990 WR-ALC began evaluating CO_2 pellet blasting to remove surface coatings. This program was designed to replace chemical and solid media blasting processes which are extremely burdened with hazardous waste management and disposal costs. While CO_2 pellet blasting removed coatings, the process was somewhat slower than expected and some questions regarding substrate damage resulting from CO_2 pellet impingement arose.

In mid 1990 McDonnell Douglas Aerospace, Cold Jet, Inc., and Maxwell Laboratories, Inc. jointly developed the concept that by using a synergistic approach, the flashlamp technology and CO_2 pellet blasting could be used in concert to remove surface coatings, keep the lamp clean, remove the resulting soot, and provide substrate cooling. This activity led to the development of the first flashlamp/CO_2 advanced coatings removal prototype.

In April 1991 WR-ALC let the contract with McDonnell Douglas to develop and demonstrate a prototype system to be installed on a robot for F-15 composite parts paint stripping.

2.0 EXECUTIVE SUMMARY.

2.1 Application -

Increasingly stringent environmental regulations (Clean Air Act 1990) controlling the use and disposal of hazardous and toxic materials; concerns over personnel health and safety; aging aircraft structural integrity; and the increasing use of composites are the issues which form the foundation for the development of an environmentally compliant alternative to aircraft paint stripping.

As the environmental issues associated with aircraft paint stripping become more pressing, interim partial solutions were implemented. While these solutions were more acceptable with respect to replacing toxic chemicals, they only treated the most obvious symptom of the problem. Still to be resolved were the issues of potential airframe structural damage by the media used, aircraft downtime due to precleaning and extensive masking to prevent media intrusion, media recycling and disposal costs, post stripping cleanup, and the repair of sealants which are often damaged or destroyed during chemical or solid/liquid media impingement paint removal. A graphic comparison of these issues as they are associated with various paint stripping processes is presented in Figure 1, Investigation of Paint Strip Processes.

Test data included in this report will show that when properly applied, xenon flashlamp and carbon dioxide advanced coatings removal is benign to both metallic and composite structures. Also, toxic waste is reduced as are maintenance manhours and aircraft through-put time.

2.2 Accomplishments -

The objective of the PRAM project to demonstrate proof-of-concept paint stripping, particularily on composite substrates, has been successfully accomplished. The WR-ALC demonstration was held on 24-25 September 1992. The demonstration consisted of robotically applied xenon flashlamp/CO_2 stripping of F-15 boron/epoxy vertical stabilizers (Figure 2. WR-ALC Installation).

2.3 Program Cost -

Contract value of the PRAM project was \$490,000. An additional \$162,300 in contractor cost share was used to enhance the composite parts stripping capabilities of the 6-inch PRAM project prototype.

Technology / Characteristics	Xenon Flashlamp/ CO2 Pellet Blasting	CO2 Pellet Blasting	Xenon Flashlamp	LASER	Water Ice Blasting	Sodium Bicarbonate Blasting	Non-Phenol Based Chemical Softener/ Waterjet	High Pressure Water Jet (32,000 psi)	Wheat Starch Blasting	Phenol Based Chemical/ Water Rinse	Plastic Media Blasting (PMB)
Hazardous Waste Volume	Low (No Media)	Low (No Media)	Low (No Media)	Low (No Media)	Low	Low	Moderate	Low	Low	High	Moderate
Media Disposal Cost	None	None	None	None	None	Low	Low	None	Low	Very High	High
Media Recycle Requirement	None	None	None	None	Yes	Yes	None	Yes	Yes	None	Yes
Aircraft Precleaning Required	None	None	None	None	None	None	Yes	None	Yes	Yes	Yes
Adjacent Componen Damage Potential	None	None	None	Low	Low	Yes	Low	High	Yes	Yes	Yes
Corrosion Potential	None	None	None	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Media Intrusion Potential	None	None	None	None	High	High	High	High	High	High	High
Post Stripping Cleanup Required	None	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AircraftThru-Put Rate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate	Low	Moderate
Paint Stripping Rate	High	Moderate	Low to Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Aircraft Damage Potential	Low	Moderate	Minimal	Low	Low	Low	Moderate	Moderate	Low	High	Moderate
Aircraft Masking Requirement	Minimal	Minimal	Minimal	Minimal	Extensive	Extensive	Extensive	Extensive	Extensive	Extensive	Extensive
Operator Safety Requirements	Ear/Eye	Ear/Eye	Ear/Eye	Lethal Energy	Eye	Breathing Ear Eye	Chem Burn	Lethal Blast	Breathing Ear Eye	Chem Burn	Breathing Ear Eye

Characteristics Rating

Best | Moderate | Worst

Figure 1. Investigation of Paint Strip Processes

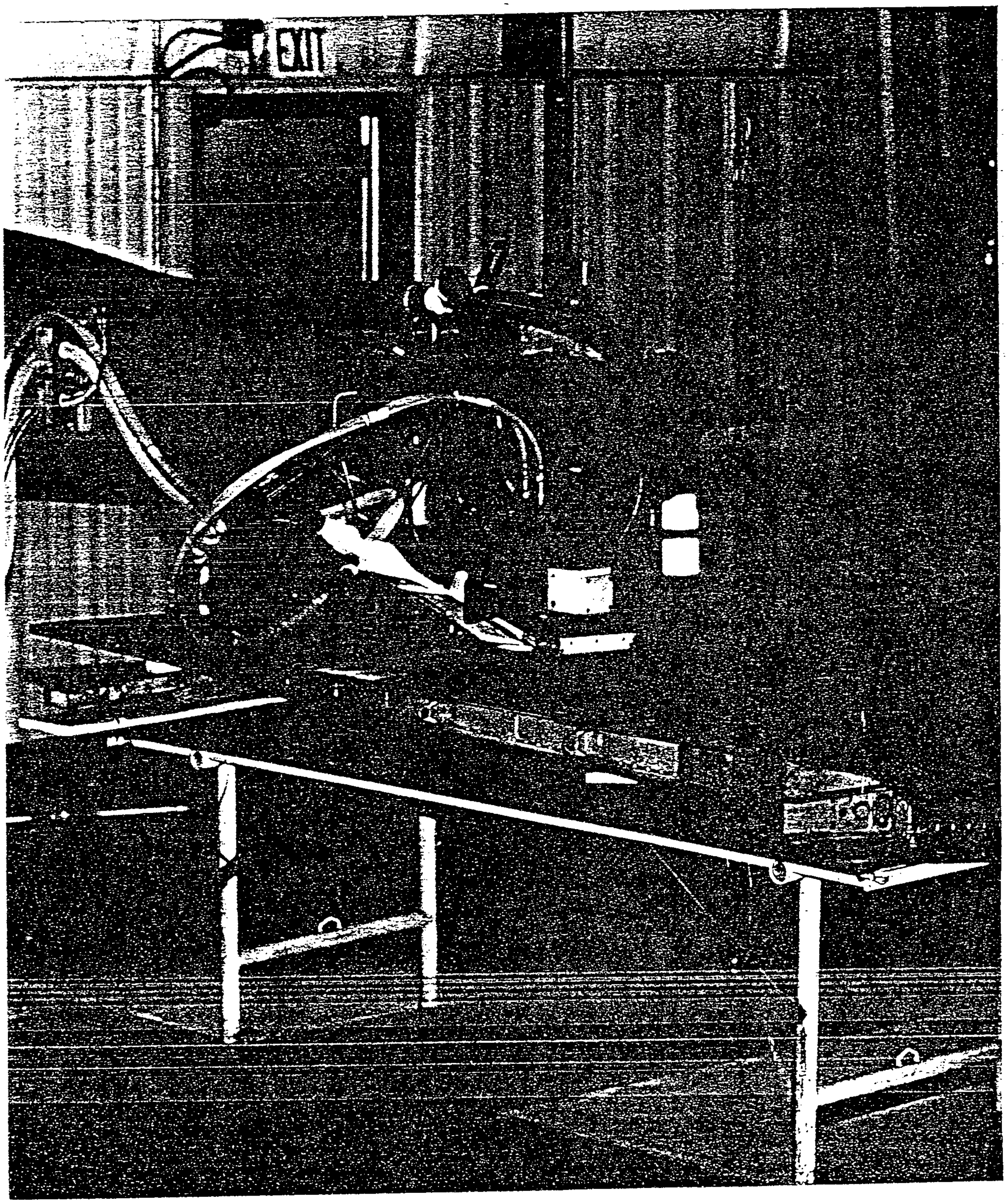


Figure 2. WR-ALC Installation

3.0 TECHNICAL DISCUSSION.

3.1 System Description -

The PRAM Project prototype system consists of a stripping head, high voltage power supply/controller, and a government furnished CO_2 pellet blasting system.

3.1.1 Stripping Head - The prototype stripping head consists of a flashlamp module which contains the 6-inch lamp, reflector, and water cooling system. Bracketry for mounting provisions for the 6-inch wide CO_2 nozzle, motion and proximity sensors and effluent capture shroud are attached to the flashlamp module resulting in an integrated unit, Figure 3. PRAM Stripping Head.

3.1.2 High Voltage Power Supply - The high voltage power supply provides the energy to operate the flashlamp. Computer control is provided for flashlamp energy levels and pulse rates. The deionized water cooling reservoir, pumps, and filters are also located within the cabinet, Figure 4. High Voltage Power Supply.

3.1.3 CO_2 Pellet Blasting System (GFE) - The CO_2 pellet blasting system, Cold Jet Model 65-200 (Figure 5.), manufactures pellets from liquid CO_2 and provides a means of delivery and control to the nozzle of the stripping head.

3.2 Process Description -

The pulsed light energy source consists of a quartz tube filled with xenon gas which when electrically energized, emits a brilliant flash of light. As the paint absorbes the photon energy, its temperature rapidly rises to the point at which a thin layer (approximately 1 mil per pulse) is ablated and released from the surface. Rapid pulsing of the lamp results in an excellent paint removal rate with no damage to the substrate. As the paint coating is ablated, the residue is simultaneously removed from the surface by the low pressure CO_2 particle stream.

CO_2 gas (source of the dry ice pellets) is a by-product of many other industrial processes. If left uncollected, the gas is vented to atmosphere. This gas is collected, purified, and converted to a liquid state. Liquid CO_2 is then compressed into pellets and delivered to the painted surface in a low pressure air stream. Upon impact, the pellets sublime to a gaseous state.

The synergism achieved with the Xenon Flashlamp/CO_2 coatings removal process results in the perfect means to remove paint and clean the surface in one operation. As quickly as the pulsed light energy ablates the paint, the continous flow of CO_2 pellets sweeps away the residue. The heating effect of pulsed light energy is offset by the cooling effect of the CO_2 flow. During the stripping process, the continous flow of CO_2 pellets also maintains the cleanliness of the flashlamp window ensuring maximum transmission of photon energy to the surface. The CO_2 rich environment at the point of ablation also provides an atmosphere which will not support combustion.

3.3 Process Control -

A major advantage of the Xenon Flashlamp/CO_2 Coatings Removal Process over current and other developmental processes is the degree of control achievable. By varying operating parameters such as pulsed light energy density, stripping head rate of travel and standoff; and CO_2 delivery pressure and nozzle angle, varying degrees of paint stripping can be achieved. These degrees of stripping include: complete finish system removal (top-coats and primer) to bare metal; removal of only selected layers of topcoats leaving the primer intact and undamaged; and chemical free cleaning of surfaces using only the CO_2 pellet stream.

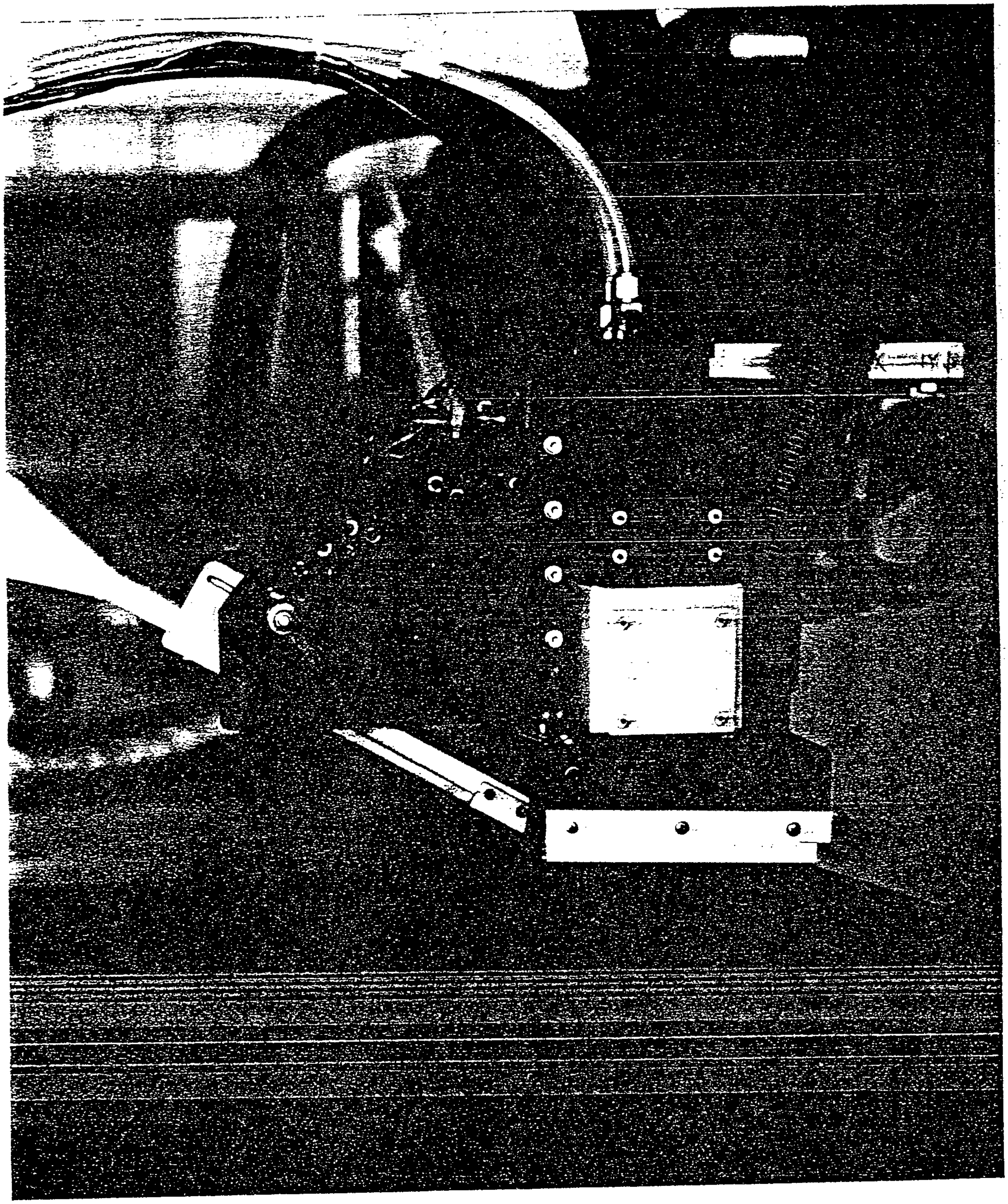


Figure 3. PRAM Stripping Head

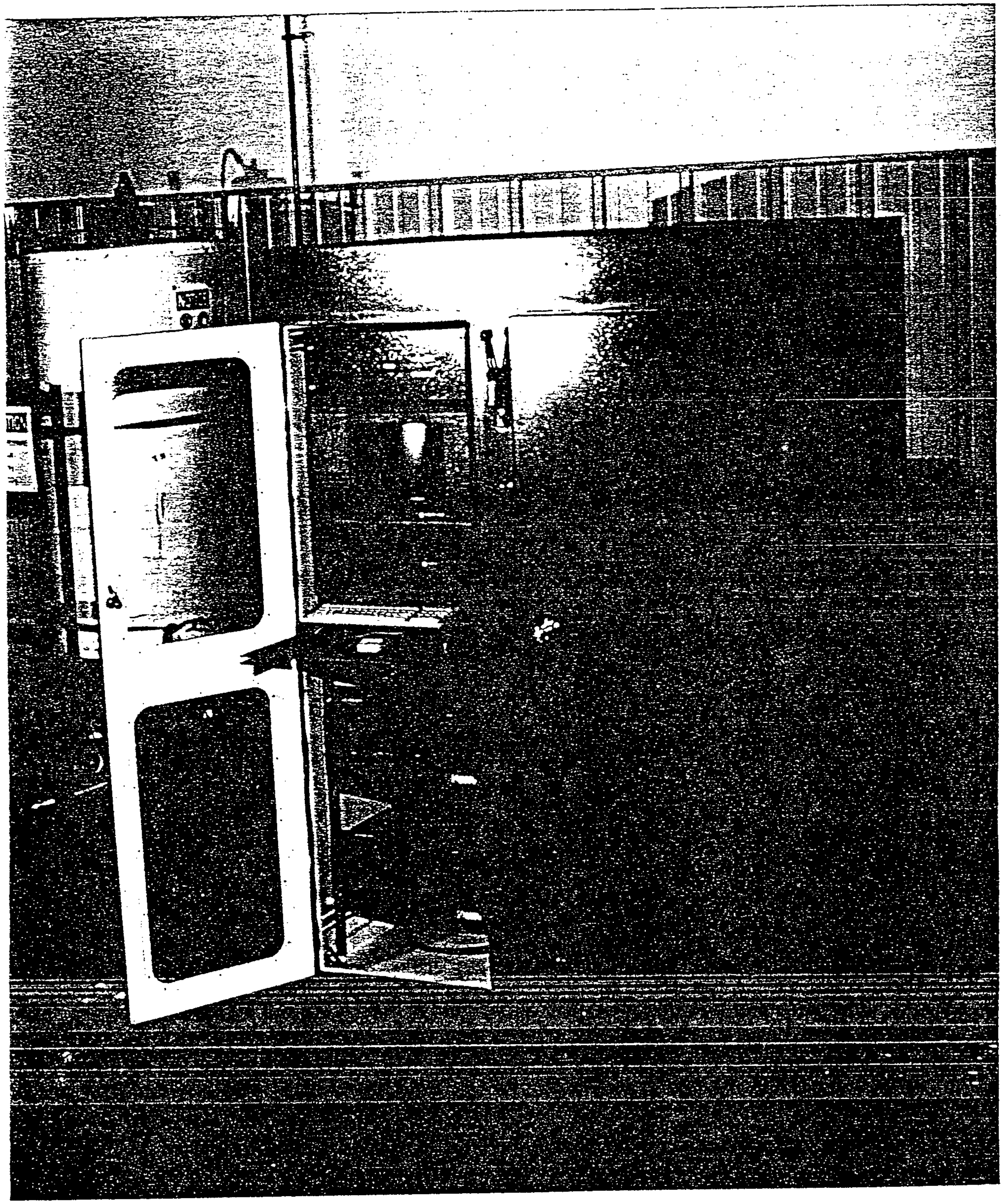


Figure 4. High Voltage Power Supply

Figure 5. Cold Jet Model 65-200

This selective stripping capability is in stark contrast to all chemical and most liquid/solid media impingement processes which are limited to removing the entire finish system to substrate. Selective stripping is particularily attractive for composite substrates whereby leaving the primer precludes any subsequent damage.

The increased use of composites in aircraft construction has introduced a unique set of problems relating to paint stripping. Many chemical strippers attack composite resins as they destroy the paint/primer molecular bond. Also, composites are particularily susceptible to damage from high velocity solid or liquid media. By using the control option available to remove only topcoats and leave the primer intact, the Xenon Flashlamp/CO_2 Coatings Removal Process provides a capability which is impossible to attain with most other paint stripping processes.

3.4 **Reliability & Maintainability** -
Manufacturers of the components which comprise the Xenon Flashlamp/CO_2 system were selected partly for their attention to providing a high degree of system reliability and maintainability. McDonnell Douglas Aerospace (MDA), as prime contractor, and Maxwell Laboratories and Cold Jet are familiar with and have designed and built their respective equipment with high reliability and maintainability as a prime consideration.

3.4.1 Maxwell Labs Flashlamp System - Due to the prototype status of the stripping head and power supply, no current historical data base exists. MDA is monitoring and collecting R&M data for further analysis. Predicted service life of the pulsed power system is 20,000 operating hours. Known maintenance factors include:

- Lamp Cost - $250-$300 ea
- Lamp Life - 8 hours (6-inch prototype)
- Lamp Replacement Time - 15 minutes

3.4.2 Cold Jet Model 65-200 - The Cold Jet unit has been commercially available since 1990. Documented R & M data includes:

- Design Service Life - 10,000 Hours
- Current MTBF - 1,000 Hours
- Current MTTR - 4 Hours (one technician)
- Scheduled Maintenance Interval - 500 Hours (Inspect, Change Filters, Lubrication)

4.0 MECHANICAL PROPERTIES TESTS.

This section includes:

- U.S.A.F. Material Test Matrix, Table 1
- U.S.A.F. Coatings Test Matrix, Table 2
- Ultrasonic Inspection Results From Paint Stripped Specimens-Composites
- Characterization of Paint Stripping Effects on Composite Material Strength-Mechanical Test Report

Final mechanical properties tests reports for metal specimens are scheduled to be completed 90 days after issuance of this report. Upon completion, the final test reports will be issued as an addendum to this report.

Table 1. U.S.A.F. Material Test Matrix

MATERIAL	TEST(S)
2024-T3 BARE (0.032 INCH) 7075-T6 BARE (0.032 INCH)	FATIGUE CRACK GROWTH ALMEN STRIP REPAINT ADHESION CORROSION RESISTANCE
2024-T81 BARE (0.020 INCH) FACE PLATE/HONEYCOMB SANDWICH ASSEMBLY, MIL-A-25463, TYPE II, CLASS I, ADHESIVE	CLIMBING DRUM PEEL
7075-T6 BARE (0.020 INCH) FACE PLATE/HONEYCOMB SANDWICH ASSEMBLY, MIL-A-25463, TYPE II, CLASS I, ADHESIVE	CLIMBING DRUM PEEL
7075-T6 CLAD (0.125 INCH) 2024-T3 CLAD (0.125 INCH)	EFFECT ON METALLIC SURFACE FINISHES (ALCLAD, IVD, Al, Cd)
6-4 TITANIUM	REPAINT ADHESION
BORON/EPOXY (0.060 INCH) FIBERGLASS (0.060 INCH)	COMPRESSION-FILLED HOLE
MIL-S-83430, CLASS B, POLYSULFIDE	BUTT JOINT SEALANT DEGRADATION

Table 2. U.S.A.F. Coatings Test Matrix

MATERIAL	STRIP RATES (Square Feet per Minute)			
	6-INCH		12-INCH	
	TO PRIMER	TO METAL	TO PRIMER	TO METAL
MIL-P-23377 EPOXY PRIMER MIL-C-83286 POLYURETHANE TOPCOAT (LIGHT GRAY - #36375)	1.0 - 1.5	0.3	2.5 - 3.0	1.0 - 1.5
MIL-P-87112 POLYSULFIDE PRIMER MIL-C-83286 POLYURETHANE TOPCOAT (GRAY - #36118)	TBD	TBD	3.0 - 4.0	2.0 - 2.5
TT-P-2760 POLYURETHANE PRIMER (KOROFLEX) MIL-C-83286 POLYURETHANE TOPCOAT (GRAY - #36118)	TBD	TBD	3.0 - 4.0	1.8 - 2.3
MIL-P-23377 EPOXY PRIMER MIL-C-85285 HIGH SOLIDS POLYURETHANE TOPCOAT (GRAY - #36118)	TBD	TBD	2.5 - 3.0	1.8 - 2.3

6-INCH - PRAM PROTOTYPE PAINT STRIPPING SYSTEM
12-INCH - PRODUCTION CAPACITY SYSTEM

4.1 Ultrasonic Inspection Results From Paint Stripped Specimens.

The MDA Nondestructive Testing Laboratory, Dept. 257, received three (3) specimens for ultrasonic inspection, looking for damage induced from a paint strip operation (xenon flashlamp/CO_2). The specimens consisted of two skin sections made of carbon-bismaleimide and a section of F-15 fiberglass radome.

The two carbon-bismaleimide specimens were inspected using an immersion through-transmission reflectorplate method. This method was performed using a 1/2 inch diameter, 7.5 mhz alpha transducer at a focal length of 4.0 inches. The F-15 radome specimen was inspected by the through-transmission squirter method. This method was performed using two 3/4 inch diameter, 5.0 mhz gamma transducers at a focal length of 5.5 inches.

The ultrasonic inspections performed on the three specimens provided revealed no discernible evidence of damage caused by the xenon flashlamp/CO_2 paint stripping operation.

4.2 Characterization of Paint Stripping Effects on Composite Material Strength-Mechanical Test Report.

4.2.1 Introduction - A primary concern in choosing a paint stripping method, either thermal, mechanical, or chemical, is whether the chosen method will cause any damage to the underlying substrate or cause changes to the physical properties of the material; therefore, MDA fabricated boron/epoxy and fiberglass laminates for open-hole compression testing after paint stripping using the xenon flashlamp/carbon dioxide coatings removal process.

4.2.2 Specimen Manufacture - Boron/epoxy and fiberglass specimens were fabricated by MDA and primed and painted, Table 3. Mechanical Properties-Composites Test Matrix. Some of the specimens were left painted while others were stripped to primer or to substrate to provide a controlled sampling for evaluation. The specimens were then machined and strain gage tested for this preliminary evaluation of the xenon flashlamp/CO_2 coatings removal process. Figure 6. Compression Specimen, shows specimen size and strain gage locations.

Table 3. Mechanical Properties-Composites Test Matrix

MATERIAL	LAYUP	COLOR	CONDITION	NO. OF SPECIMENS
BORON/EPOXY	[±45/02/902]s	SILVER	PAINTED	4
BORON/EPOXY	[±45/02/902]s	LT. GREEN	STRIPPED TO PRIMER	3
BORON/EPOXY	[±45/02/902]s	BLACK	STRIPPED TO SUBSTRATE	4
FIBERGLASS	[±45/0]s	SILVER	PAINTED	5
FIBERGLASS	[±45/0]s	LT. GREEN	STRIPPED TO PRIMER	4
FIBERGLASS	[±45/0]s	DK. GREEN	STRIPPED TO SUBSTRATE	5

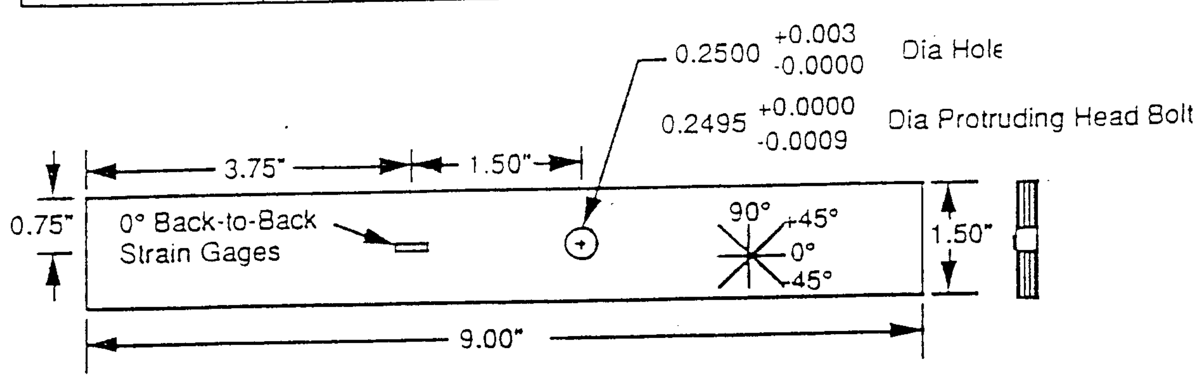


Figure 6. Compression Specimen.

4.2.3 Mechanical Testing - Because the twenty-five (25) specimens were thin (varying from 0.049 to 0.065 inch in thickness), a compression fixture was machined to prevent specimen buckling during the static strain-gage testing. Figure 7. Compression Fixture, shows the compression fixture used for the open hole tension and compression tests. All testing was done in accordance with McAir P.S. 21151.10, Test Methods for Composites: Open Hole Tension and Compression.

4.2.4 Discussion - The test results reveal that neither the boron/epoxy nor the fiberglass specimens show any signs of mechanical property degradation caused by the xenon flashlamp/CO_2 stripping process when the specimens were stripped of only the topcoats leaving the primer intact. The optimum intended method of stripping composite substrates is to leave the primer intact, thus precluding any physical damage to the substrate. Current U.S.A.F. publications, T.O. 1-1-8, Application and Removal of Organic Coatings, Aerospace and Non-Aerospace Equipment states that during paint removal on composite materials "..remove the paint coat and leave as much of the original primer on the surface as possible..."

The test results show a slight increase in the ability of the composite to withstand compression. This noted increase in strength is most likely due to scattering (noise) in the statistical data; i.e, primer does not increase the strength of boron/epoxy or fiberglass. However, when the specimens were stripped of both topcoats and primer to bare substrate (contrary to the intended method and T.O. 1-1-8), a degradation in compression strength was noted. The full tests results are detailed in Table 4. Filled/Open Hole Compression Test Data.

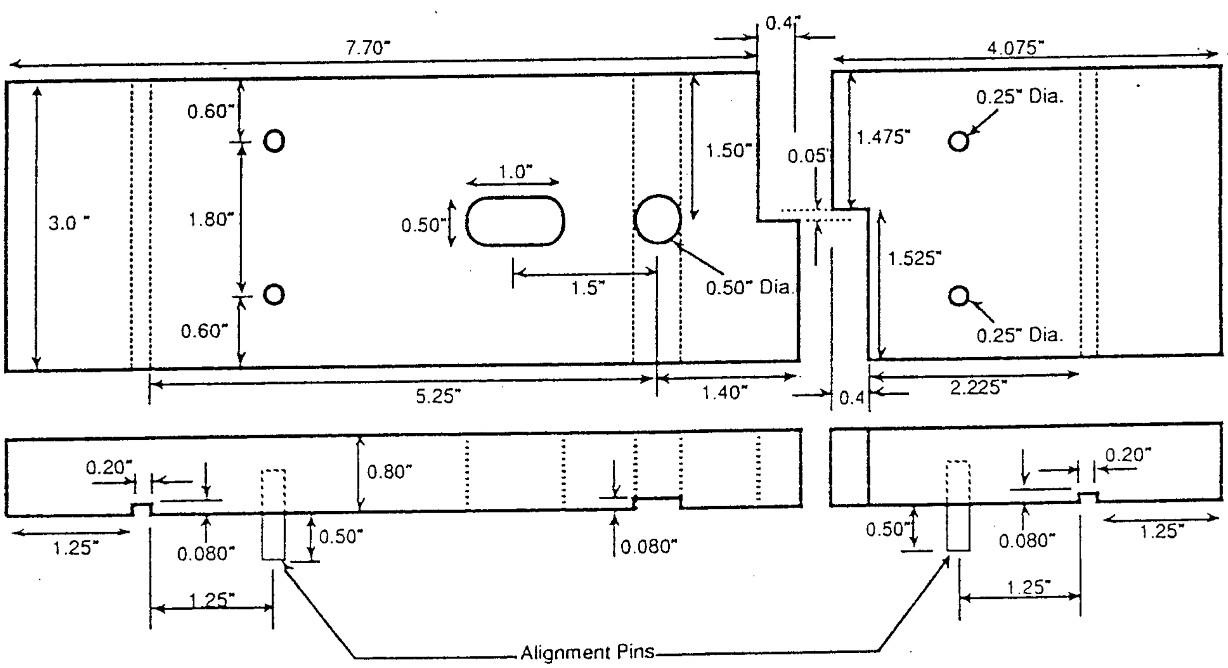


Figure 7. Compression Fixture

Table 4. Filled/Open Hole Compression Test Data

TEST TYPE (2)	LAMINATE TYPE	CONDITION	SPEC. ID	SPECIMEN DIMENSIONS WIDTH	THICK	DIAM	FAILING LOAD (LBS)	FAILING STRESS (KSI) (4) INDIV	AVG	INITIAL MODULUS (MSI) (3) INDIV	AVG	FAILING STRAIN (-uIN/IN) G-1	G-2	AVG	NOTES
FILLED HOLE	BORON/ EPOXY	UNSTRIPPED	8B2-1	1.502	0.062	0.250	8760	94.1	93.4	14.11	14.1	6400	6950	6945	(6) (8)
			8B2-2	1.502	0.061	0.250	8550	93.3		14.28		6290	6800		(6) (8)
			8B2-3	1.496	0.063	0.250	8890	94.3		13.89		6680	6820		(6) (8)
			8B2-4	1.501	0.062	0.250	8540	91.8		14.12		5890	7210		(6) (8)
		STRIPPED TO PRIMER	8B2-5	1.497	0.062	0.250	9110	98.2	94.4	14.05	14.1	7080	6890	6953	(6) (8)
			8B2-6	1.499	0.062	0.250	8760	94.3		13.99		6090	7330		(6) (8)
			8B2-7	1.502	0.062	0.250	8450	90.7		14.17		6160	6640		(6) (8)
		STRIPPED TO SUBSTRATE	8B4-1	1.500	0.065	0.250	8670	88.9	89.8	13.39	13.5	6240	7030	6883	(6) (8)
			8B4-2	1.506	0.064	0.250	8920	92.5		13.53		6530	7100		(6) (8)
			8B4-3	1.507	0.064	0.250	8480	87.9		13.51		6500	6460		(6) (8)
	FIBERGLASS	UNSTRIPPED	9B2-1	1.503	0.051	0.250	2450	33.1	33.8	3.15	3.2	11640	11570	12570	(6) (7)
			9B2-2	1.504	0.052	0.250	2630	33.6		3.21		11290	12630		(6) (7)
			9B2-3	1.504	0.052	0.250	2720	34.8		3.22		11880	13020		(6) (7)
		STRIPPED TO PRIMER	9B3-1	1.500	0.052	0.250	2780	35.6	34.7	3.12	3.2	12660	13710	12753	(6) (7)
			9B3-2	1.500	0.052	0.250	2610	33.5		3.18		11880	11840		(6) (7)
			9B3-3	1.500	0.052	0.250	2740	35.1		3.18		12920	12710		(6) (7)
		STRIPPED TO SUBSTRATE	9B4-3	1.502	0.054	0.250	2460	30.3	28.2	3.11	3.2	11930	11310	10167	(6) (7)
			9B4-4	1.499	0.054	0.250	2020	25.0		3.36		8480	9490		(6) (7)
			9B4-5	1.499	0.049	0.250	2150	29.3		3.27		10090	9700		(6) (7)
OPEN HOLE	BORON/ EPOXY	STRIPPED TO SUBSTRATE	8B4-4	1.485	0.064	0.250	7450	78.4		13.51		5330	5980		(6) (8)
	FIBERGLASS	UNSTRIPPED	9B2-4	1.504	0.052	0.250	2020	25.8		3.33		8670	8690		(6) (7)
			9B2-5	1.503	0.052	0.250	2070	26.5		3.33		8620	9100		(6) (7)
		STRIPPED TO PRIMER	9B3-4	1.497	0.052	0.250	2010	25.8		3.11		8490	9040		(6) (7)
		STRIPPED TO SUBSTRATE	9B4-1	1.501	0.054	0.250	1512	18.7		3.03		7700	5580		(6)
			9B4-2	1.504	0.054	0.250	1200	14.8		(5)		(5)	(5)		(6)

NOTES:

1. ALL THE SPECIMENS WERE TESTED AT ROOM TEMPERATURE.
   THE LOADING RATE WAS 0.05 IN/MINUTE.

(2) A 0.250 INCH DIAMETER FASTENER WAS USED FOR THE FILLED HOLE TESTS. THERE WAS NO CONTACT BETWEEN BOLT HEAD OR NUT AND SPECIMEN.

(3) THE FINAL MODULUS WAS DETERMINED BY LINEAR REGRESSION OF THE AVERAGE STRAINS ASSOCIATED WITH THE LOADS BETWEEN 6% AND 35% OF THE FAILING LOAD

(4) THE FAILING STRESS WAS CALCULATED BY: $\frac{P}{wt}$ WHERE: P = FAILING LOAD (LBS)
w = SPECIMEN WIDTH (IN)
t = SPECIMEN THICKNESS (IN)

(5) STRAIN GAGE LEADS SHORTED AGAINST FIXTURE.

(6) SPECIMEN FAILED AT HOLE.

(7) INCIDENTAL DAMAGE OCCURRED AT END OF SPECIMEN.

(8) INCIDENTAL DAMAGE OCCURRED 2.5 INCHES FROM END OF SPECIMEN.

Table 5. Open Hole Compression Summary

MATERIAL	CONDITION	AVERAGE FAILURE STRESS (ksi)	DEGRADATION (IMPROVEMENT) %
BORON/EPOXY	UNSTRIPPED	93.4 ± 1.6	---
	STRIPPED TO PRIMER	94.4 ±3.8	(1.07)
	STRIPPED TO SUBSTRATE	89.9 ± 2.7	3.75
FIBERGLASS	UNSTRIPPED	33.8 ± 1.0	---
	STRIPPED TO PRIMER	34.7 ±1.2	(2.66)
	STRIPPED TO SUBSTRATE	28.2 ± 3.2	16.57

4.2.5 Conclusion - The engineers who conducted the mechanical properties testing on these composites feel that the degradation observed on the fiberglass specimen stripped to substrate, Table 5. Open Hole Compression Summary, is due to a significant loss of resin at the outer surface. This observation is further strengthened by the fact that little or no degradation occurred to the fibergalss specimens when paint stripping of only topcoats, leaving the primer intact.

5.0 OCCUPATIONAL HEALTH HAZARD ASSESSMENT REPORT.

5.1 Introduction.

In early December 1991, the McDonnell Douglas Aerospace (MDA) Analytical Chemical Laboratory (ACL) was requested to analyze the effluents resulting from the xenon flashlamp/CO_2 paint removal process and develop preliminary design parameters for an effluent capture and filtration system. This system is required for use in the collection and removal of dusts, fumes, vapors, and organic contaminants resulting from the operation of the xenon flashlamp/CO_2 paint removal process. A preliminary system was designed around an American Air Filter Model AR ARRESTAL Dust Collector series and the Invincible Airflow Systems Model 6000-7.5. Absorption and filtration media for collection of contaminants were identified and specified.

5.2 Health Hazard Evaluation.

5.2.1 Evaluation Design - Particulates (such as dusts and fumes), vapors and organic constituents must be captured as close to the point of generation as possible for efficient removal. To fulfill this requirement a collection system (Figure 8) was designed exhibiting the following characteristics:

- Attaches to current stripping head/ collection box assembly
- Two 2.5 inch ducts are joined into one 4 inch flexible duct
- 400+ CFM volumetric flowrate
- >3500 FPM duct velocity
- >300 FPM face velocity
- Blower system capable of approximately 60 inch W.G.
- Heater capable of maintaining inlet air temperature at 70 degrees F

5.2.2 Description of the Evaluation Process - A prototype xenon flashlamp/CO_2 paint stripping system was constructed at Maxwell Laboratories, Inc., San Diego, CA. The prototype site was visited by MDA ACL employee Dale Scheer in October 1992. Samples of the effluent given off during the operation of the xenon flashlamp/CO_2 paint removal process where taken as described in paragraph 5.2.3 Methods. Preliminary analytical data indicated the particle size to be in the low micron range; therefore, a high flowrate and face velocity is required to capture the particulate matter. Concurrently, a high duct velocity is required to keep the captured particles moving. The American Air Filter ARRESTAL AR series and Invincible Airflow Systems Model 6000-7.5 comply with the listed requirements.

5.2.3 Methods - Two prepared aluminum panels were spray painted with F-15 topcoat and allowed to air dry. The panels were placed in a stainless steel chamber fitted with a 2 1/2 inch diameter quartz window. The chamber was assembled and seal integrity verified to two atmospheres pressure. Figure 9 is a photograph of the chamber prior to exposure. The panels were exposed to the xenon flashlamp through the quartz window. Figure 10 is a photograph of the chamber after exposure. All volatile materials were contained within the sealed chamber. The chamber was returned to the ACL for analysis. The chamber atmosphere was analyzed by capillary column gas chromatography/mass spectrometry (GM/MS) utilizing cryofocusing techniques. Compounds were identified by comparison of the mass spectral data to the Hewlett-Packard GC/MS on-board library.

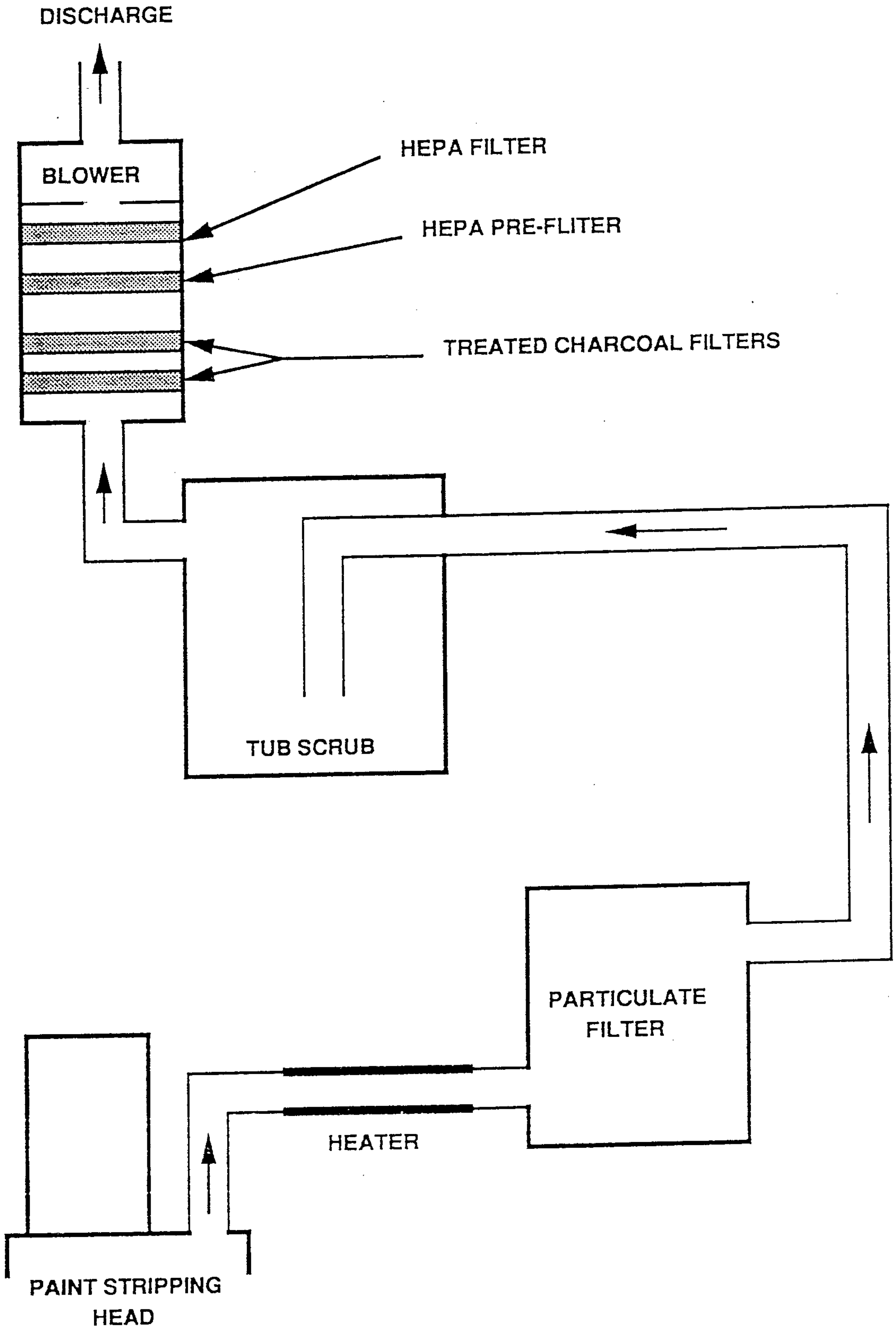
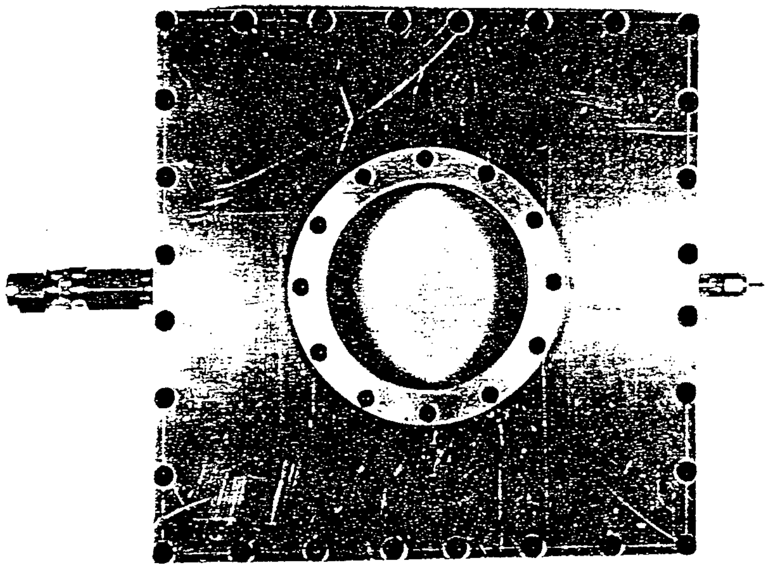
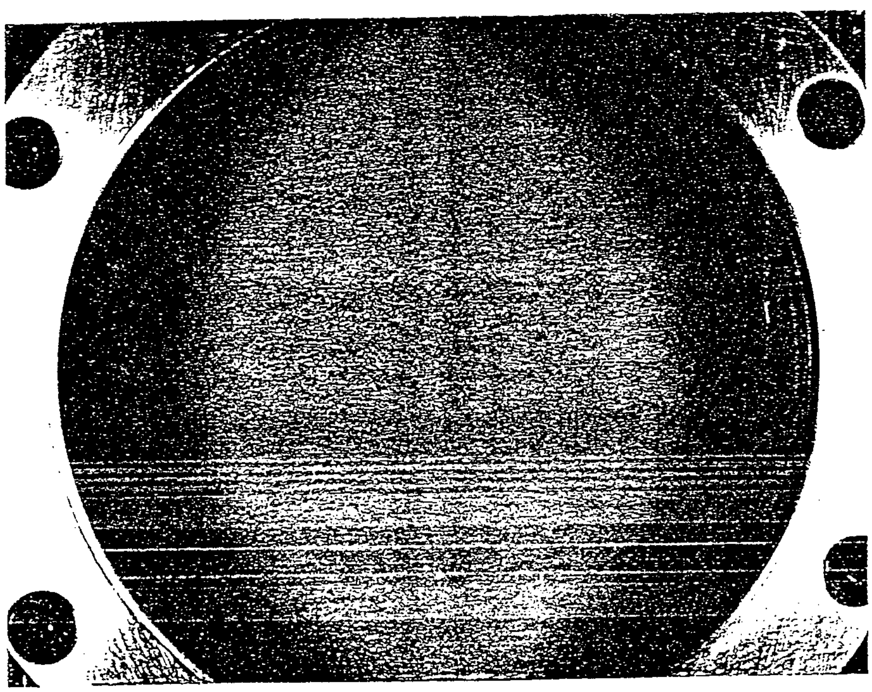


Figure 8. Xenon Flashlamp/CO_2 Effluent Capture System

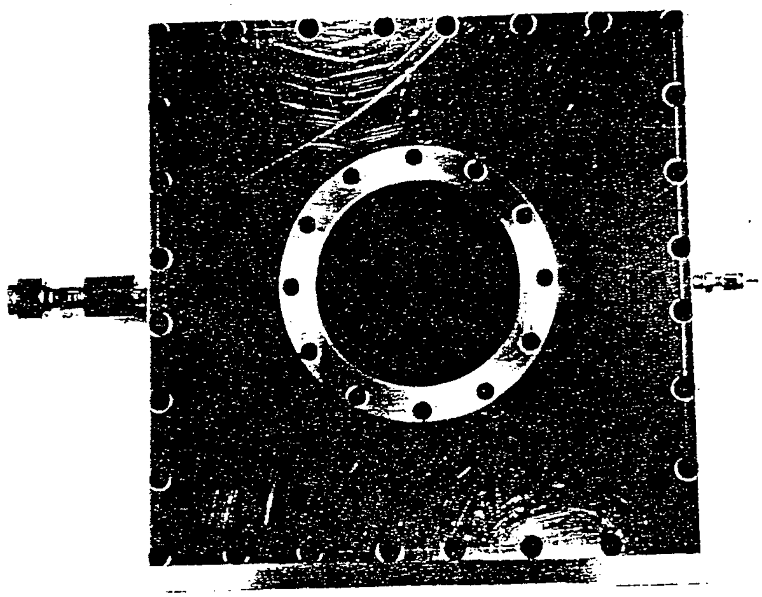


TEST PANEL SEALED IN EFFLUENT CAPTURE CHAMBER
BEFORE EXPOSURE TO FLASHLAMP

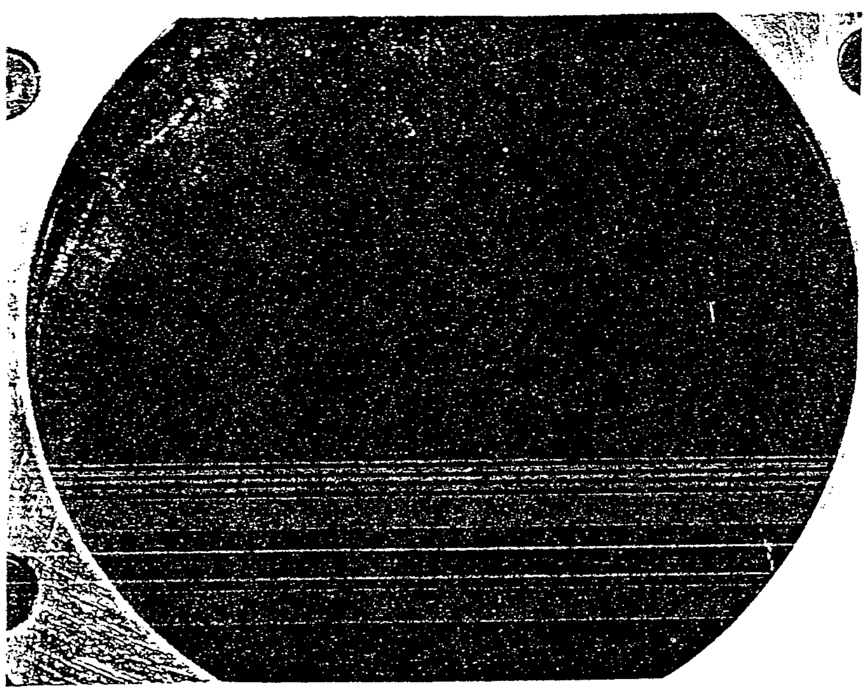


CLOSE-UP OF TEST PANEL UNDER QUARTZ WINDOW

Figure 9. Effluent Capture Chamber (Before Exposure to Flashlamp)



TEST PANEL SEALED IN EFFLUENT CAPTURE CHAMBER
AFTER EXPOSURE TO FLASHLAMP



CLOSE-UP OF TEST PANEL UNDER QUARTZ WINDOW

Figure 10. Effluent Capture Chamber (After Exposure to Flashlamp)

5.3 **Evaluation Results.**

5.3.1 Environmental Sampling - Sample measurements where taken from the sealed chamber through the chamber's port. Off-gas compounds resulting from the xenon flashlamp testing are listed in Table 6. Stripped Paint Effluents.

5.3.2 Medical - The medium used in this operation is pelletized carbon dioxide. As solid carbon dioxide warms, it sublimes to the gas phase. For this reason, we have designed a gaseous CO_2 monitor into the system which will effect a total system shut-down should the ambient CO_2 level become unsafe by displacing the oxygen content of the ambient air. This device will also prohibit the system from restarting until the ambient CO_2 levels fall below the unsafe threshold.

5.4. **Conclusions.**

The test objective of doing analysis and developing the preliminary design parameters for an effluent capture and filtration system used with the xenon flashlamp/CO_2 paint stripping process has been completed. The self-contained dust collector system identified in paragraph 5.2.1 meets the requirements of this capture system. American Air Filters (AAF) Model AR ARRESTAL and Invincible Airflow Systems Model 6000-7.5 units meet and/or exceed all the technical considerations listed. These systems are a compact and highly effieient dust collectors. They are relatively inexpensive, readily available and require little maintenance. These units provide a cleaning efficiency of 95% for particulate matter greater than or equal to 1 micron in size. Thus, for every 100 pounds of 1 micron or larger particles delivered to the inlet, an ARRESTAL will remove 95 pounds. The dust collector will be equipped with a photomagnehelic interlock which will shut the entire system down for cleaning when the pressure drop across the fabric exceeds a predetermined value. This unit will be equipped with an automatic shaker motor. Dusts are known for their static electric characteristics and the inherent potential danger; therefore, both the unit and the ducting will be static discharge protected. The effluent from the dust collection phase stage will then be directed to the chacoal filter stage.

Activated charcoal filter media is well known for its capability to remove organic components. Activated charcoal removes virtually all organics; i.e., its removal efficiency is greater than 99%. A charcoal unit, TUB SCRUB, manufactured by Cameron-Yakima Inc. has been identified as a possible source for activated charcoal filtration equipment. The TUB SCRUB unit is capable of handling the flows required for the paint stripping operation.

Research into the subject of a capture system revealed a company which manufactures advanced gas-phase air purification equipment. Extraction Systems Inc. manufactures a line of carbon filters under the trade name of DPCC ABSORBERS. These filters are constructed of carbon-impregnated pleated fiber filter media. In addition, this firm can supply a variety of carbon chemistries that are tailored for specific compound removal applications. They are able to chemically treat the charcoal in such a way that the filter exhibits enhanced specific compound collection. For example, some treated units will remove virtually 100% of compounds such as formaldehyde, ozone and/or acid gases. Other elements will remove virtually all incoming odors and hydrocarbons. The elements have a filtration area of 164 square meters and are 12 inches deep yet they exhibit little air flow resistance

Table 6. Stripped Paint Effluents

OFF-GAS COMPOUNDS IDENTIFIED FROM XENON FLASHLAMP TESTS	
2-methyl-1-propene	* 1,3-butadiene
* acetaldehyde	1,3-buten-3-yne
1,3-butadiyne	ethanol
cyclopentadiene or 1.3-pentadiene	1-pentene
2-pentene	isopropyl alcohol
2-propanone	2-methyl-1,3-butadiene
* acetonitrile	1,2-pentadiene
1,3-cyclopentadiene	2-propenenitrile
1-hexyne	propylcyclopropanr or methylcyclopentane
2,5-dihydrofuran	4-methylcyclopentene
1,4-hexadiene	nitromethane
ethoxyethene	1,1,1-trichloroethane
1-butanol	* benzene
2,4-hexadiene	* 4-methyl-2-pentanone
2-methly-1-propene	toluene
2,4-pentadione	butyl acetate
cyclopentanone	5-hexen-1-ol
xylene	2-heptanone
ethynylbenzene	* styrene
cyclohexanone	1,3-cyclopentanedione
1,1'-bicyclopropyl	(1-methylethenyl)-benzene
benzaldehyde	benzonitrile
2-propenylbenzene	3-butenylbenzene
2-propynylbenzene	.alpha.,.alpha.-dimethyl-benzenemethanol
1,3-diethenylbenzene	1,3-dimethyl-cis-cyclopentane
1-methyl-1H-Indene	1,2-dihydronaphthalene
* naphthalene	1-propene
ethane	ethene
acetylene	chromium
cadmium	

* Compounds listed as an Air Toxic per Clean Air Act Amendements of 1990.

(0.4" W.G.) at the design flowrate. These filter elements fit into standard holding frames which would facilitate the construction and maintenance of the filter stage.

It should be pointed out the Extraction Systems Inc. DPCC ABSORBERs were approved for use in the new National Archives facility. Prior to approval for use in the new facility, candidate filters were assessed for their effectiveness at removing specific pollutants. The specific pollutants were identified in Archives II, Degas Filters, Section 15881. Some of the specified pollutants are directly applicable to off-gas compounds resulting fron xenon flashlamp/CO_2 paint stripping. The subject testing was conducted by Battelle-Columbus under Battelle Contract 857-U-4580R, dated October 1991.

Final ultimate filtration will be achieved through the use of a HEPA pre-filter and a HEPA filter. These two filters will follow the carbon and treated carbon filter stage. The proposed HEPA pre-filter/filter combination has an efficiency of 99.97% for particulate matter in excess of 0.3 micron. The effluent from HEPA filtration is virtually free of particulate matter and/or fumes. HEPA filters are available from multiple sources. It is recommended that the final treated effluent be vented to outside air.

The filtration stages will also be configured with a photomagnehelic gauge. This unit will sense any pressure drop across the entire filter bed and shut the complete system down when a pre-determined pressure drop is reached. The pre-determined pressure drop indicates that the filter bed is "loaded" and cannot continue to adequately treat the waste air stream. The filtration system must then be serviced before the unit is allowed to be restarted.

An alternate approach to the proposed filtration system is a thermal treatment. Thermal treatment can be accomplished by thermal or catalytic incineration. Initially, this approach is somewhat more expensive; however, it is more environmentally sound. Catalytic incineration (CI) would be the better choice since these units operate at lower temperatures. This translates to an immediate cost advantage due to reduced energy consumption. Actually, energy consumption may not be an issue because the influent to the proposed filtration system requires approximately 81,000 BTU/hr heat energy input prior to the particulate trap.

Typical volatile organic compound (VOC) destruction is 95 - 99% with approximately 75% heat recovery. CI not only achieves excellent VOC reduction but also yields other advantages such as less maintenance. CO2 monitors and photomagnehelic interlocks will not be required with a CI unit. A significant advantage over the proposed filtration system is adaptablility. The CI unit will easily adapt to the destruction of virtually any paint regardless of composition. With CI, filter media treatment and disposal is not an issue.

6.0 SAFETY.

Safety requirements include noise and ultraviolet radiation protection. The noise levels result from air pressure produced by the Cold Jet unit and sonic shock resulting from the flashlamp pulse. Ultraviolet radiation is emitted from the flashlamp.

6.1 Noise Survey On The Cold Jet Cryogenic Cleaner.

6.1.1 An industrial hygiene survey was performed to determine noise levels while operating the Cold Jet unit. Samples were taken utilizing a Quest M-27 dosimeter. The instrument was calibrated before and after use.

6.1.2 The average noise level of the Cold Jet unit was 95 dBA on the A scale. Occupational Safety and Health Administration (OSHA) permissible exposure limit is 90 dBA on the A scale. Therefore, minimum hearing protection is required for personnel in the immediate operating area when the flashlamp/CO_2 system is running.

6.1.3 Sonic shock resulting from the flashlamp pulse is significantly lower than the Cold Jet unit noise. Therefore, the hearing protection used for the Cold Jet unit is adequate for sonic shock protection.

6.2 Ultraviolet Radiation Eye Protection.

6.2.1 WR-ALC/CNC requested that an evaluation of UV eye protection requirements relating to xenon flashlamp/CO_2 paint stripping operation be performed. Following are the results of that evaluation.

We evaluated the adequacy of the eye protection used by personnel in the robotics facility when the xenon flashlamp is operational. The two types of eye protection available for use are welding goggles and UVEX Topsider 9142 safety glasses with side shields. The flashlamp will normally be operated using a boot (effluent capture/noise and light abatement shroud) over the unit which will shield the lamp from emitting direct light.

For the ultraviolet (UV) radiation hazards, the critical range of wavelengths for biological effects is from 200 to 320 nanometers (nm), with 270 nm being the most critical wavelength. The output energy from the flashlamp is mainly UV when the unit is operated in the high current density mode. The safety glasses are rated by the manufacturer as screening 99.9% of the UV radiation with wavelengths below 385 nm. Both types of eye protection provide adequate protection at any distance. Personnel who are in the area when the flashlamp is in operation must wear the safety glasses.

The output energy from the flashlamp contains a significant infrared (IR) radiation health hazard when it is operated in low current density mode. However, the IR radiation is not a health concern because the workers cannot stare into the main beam and there is minute specular reflection (the IR energy is mostly absorbed by the target material).

To prevent the possiblity of eye strain (from excessive blinking) and to increase worker confidence in the goggles, it is recommended that shaded goggles be utilized.

7.0 BENEFITS.

The analysis of current and emerging paint stripping processes as depicted in Figure 1. Investigation of Paint Strip Processes, indicates that xenon flashlamp/CO_2 advanced coatings removal offers an economical, safe, and environmentally compliant process ready to meet industry's needs.

Economically, the process provides high stripping rates, approximately 1 square foot per minute to primer on composites with the prototype and significantly higher rates with the 12-inch production configuration system currently being used to complete metallic substrate testing. The system is designed to be self contained, including effluent capture, and does not require permanent facilities modifications. Concerns of safety to both airframe structures and operating personnel are of equal importance to MDA. The xenon flashlamp/CO_2 process meets these safety criteria. The xenon flashlamp/CO_2 process uses no residual solid or liquid media and does not fall into the high velocity impingment category. Environmental compliance is a major benefit of the xenon flashlamp/CO_2 process. By eliminating solid and liquid residual media, disposable hazardous waste is reduced by 99% resulting in significant waste disposal cost savings.

8.0 CONCLUSIONS.

Many emerging technologies are offered as the solution to the need for low cost, safe, environmentally compliant coatings removal. All the processes effectively strip paint and remove a variety of surface coatings; however, this is where the parallelism ends. Some are environmentally superior yet present significant hazards for operating personnel and possess a high potential for inflicting structural damage. Others, while relatively benign, require substantial aircraft preparation and extensive post stripping clean-up. Each of the considerations described in Figure 1 ultimately affects the cost of technology implementation. The final selection, therefore, would seem to be based on making compromises among the various characteristics. Fortunately, one technology stands above the rest, scoring high in all categories: The Xenon Flashlamp/CO_2 Advanced Coatings Removal Process offers the greatest benefits in cost and performance along with superior environmental compliance.

9.0 RECOMMENDATIONS/ IMPLEMENTATION.

9.1 Recommendations.

Successful demonstration of the Xenon Flashlamp/CO_2 Advanced Coatings Removal Process as a viable paint stripping technology is but the first step toward environmental compliance and reduced costs associated with this facet of aircraft depot level maintenance. Working toward the goal of a production scale paint stripping facility, the following activities are recommended:

- Fabricate and install the effluent capture system described in section 5.0.

- Develop/integrate process control sensor systems, i.e., color sensors to determine depth of coating removal; an Eddy Current Array to measure coating thickness on metal substrates; and an optical/ ultrasonic technique to determine coating thickness on non-conductive composite substrates.

- Integrate the PRAM project prototype with a robot/radome transporter to strip F-15 radomes. Incorporate process control sensor systems to facilitate automated paint stripping.

- Develop a flashlamp stripping head motion device for large aircraft non-robotic process application.

9.2 Implementation.

The recommendations presented in paragraph 9.1 will be presented in the form of PRAM Project Idea Initial Submission Write-ups. Because the scope of follow-on activities is broad and the determination as to which effort(s) should receive highest priority is customer needs driven, the project idea writeups will be submitted first in draft menu form. Pending customer response, detailed long form PRAM project requests will be prepared for each specific program.

Acknowledgements

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Appendix A
PRAM Project Six Inch Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Prototype

OPERATING AND MAINTENANCE MANUAL

McDONNELL DOUGLAS CORPORATION
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1.0 INTRODUCTION.

This manual contains functional descriptions, system operation instructions, and scheduled/ unscheduled maintenance requirements necessary to safely operate and maintain the PRAM Project 6-Inch Xenon Flashlamp and Carbon Dioxide Advanced Coating Removal Prototype System.

Detailed instructions for various subsystem components are provided in the respective manufacturer's manuals listed in the Appendices. Manufacturer's data will be referenced throughout this manual as applicable.

The basic configuration of the PRAM Project Xenon Flashlamp/CO2 prototype consists of an end effector, high voltage power supply, and a customer supplied CO2 pelletizer (Cold Jet Model 65-200). Effluent capture system requirements and equipment recommendations are included in the PRAM Project Final Report (MDC 92B0479).

The product description of the flashblast system, including xenon flashlamp, power supply, controller, and water cooling system is included in Appendix A1, Section 1 and Appendix A2, Section 1.

The product description of the Cold Jet Model 65-200 is included in Appendix A4, The Cold Jet System, page 3.

1.1 Warnings, Cautions, and Notes.

Items of special importance and critical information are identified in warnings, cautions, and notes throughout this manual and in the referenced commercial manuals. Warnings and cautions appear immediately before the step to which they apply. Notes may appear before or after the affected step.

WARNING

Warnings describe conditions or procedures that could result in injury or death if correct procedures are not followed.

CAUTION

Cautions describe conditions or procedures that could result in damage to or destruction of equipment if correct procedures are not followed. Equipment is defined as both the system components and the substrates to which the process is applied.

NOTE

Notes describe or clarify conditions or procedures.

1.2 Occupational Safety and Health Administration (OSHA) Regulations.

Regulations that cover allowable noise level exposure are described in the Hearing Conservation Program. Refer to OSHA 29 CFR 1910.95. Samples taken of dBA levels for the Cold Jet unit averaged 95 dBA. Samples were taken without the noise abatement shroud installed.

There are no OSHA regulations that cover Ultraviolet (UV) light exposure. It is considered good industry practice to comply with the recognized limits established by other safety and health groups. The American Conference of Governmental Industrial Hygienist (ACGIH) has established exposure limits for UV radiation. Refer to the Ultraviolet Radiation Section in the ACGIH Threshold Limit Value Booklet.

In the event the system is used without the effluent capture system, ensure that a suitable vacuum system is used to remove effluents away from operating personnel and that personnel in the immediate area use the appropriate breathing protection required by applicable local OSHA regulations. A listing of effluents is provided in Table 1. Stripped Paint Effluents. Refer to Table 1. and the appropriate OSHA Breathing Protection requirements relating to these effluents.

2.0 GENERAL DESCRIPTION.

The PRAM Project 6-Inch Xenon Flashlamp and Carbon Dioxide Coatings Removal Prototype consists of a stripping head, pulsed light energy power supply and controller, carbon dioxide pelletizer and delivery system, and the integration hardware necessary for safe operation.

The stripping head assembly, Figure 1. U.S.A.F. PRAM Project Prototype Stripping Head, consists of a reflector/housing, xenon flashlamp, deionized water cooling system, carbon dioxide pellet delivery nozzle, and motion/proximity safety sensing devices. Motion/proximity sensing is provided by switches and encoders which prevent inadvertent lamp pulsing. A detailed description of the motion/proximity system is included in Section 5.6 System Safety Interlocks.

The pulsed light energy power supply and controller cabinet includes all the electrical and electronic components which energize and control the flashlamp. The cabinet also contains the deionized water filtering, pumping, and heat exchangers.

The carbon dioxide pelletizer manufacturers CO2 pellets from liquid carbon dioxide and delivers the pellets to the stripping head nozzle.

3.0 INITIAL SYSTEM SETTINGS AND SET-UP.

3.1 **Safety** - The system uses high voltage electrical current, pressurized air, and hydraulic actuation. Strict adherence to all Warnings, Cautions, and Notes in the commercial manuals is mandatory. Refer to paragraph 1.1 Warnings, Cautions, and Notes for descriptions. Refer to paragraph 1.2 OSHA Regulations for detailed worker safety personal protective equipment (PPE) requirements.

3.1.1 Flashblast System -
Refer to Appendix A1, Section 2, Paragraph 2.1 Personnel Safety.

3.1.2 CCDS Power Supply -
Refer to Appendix A2, Section 2, Paragraph 2.1 Personnel Safety.

3.1.3 B-Pure Pressure Cartridge System -
Refer to Appendix A3, Page 2, Safety Information.

3.1.4 Cold Jet Model 65-200 -
Refer to Appendix A4, Page 16, Safety Requirements for Operation.

3.2 **System Set-Up** - The Flashblast/CCDS system set-up procedures are outlined in Appendices A1, A2, and A3. The Cold Jet Model 65-200 set-up procedures are outlined in Appendix A4.

Prior to operating the system, a daily inspection must be performed on all system components as folllows:

3.2.1 Stripping Head.

Materials Required

Part Number	Nomenclature
TT-I-735, Grade B	Isopropyl Alcohol

Table 1. Stripped Paint Effluents

OFF-GAS COMPOUNDS IDENTIFIED FROM XENON FLASHLAMP TESTS	
2-methyl-1-propene	* 1,3-butadiene
* acetaldehyde	1,3-buten-3-yne
1,3-butadiyne	ethanol
cyclopentadiene or 1.3-pentadiene	1-pentene
2-pentene	isopropyl alcohol
2-propanone	2-methyl-1,3-butadiene
* acetonitrile	1,2-pentadiene
1,3-cyclopentadiene	2-propenenitrile
1-hexyne	propylcyclopropanr or methylcyclopentane
2,5-dihydrofuran	4-methylcyclopentene
1,4-hexadiene	nitromethane
ethoxyethene	1,1,1-trichloroethane
1-butanol	* benzene
2,4-hexadiene	* 4-methyl-2-pentanone
2-methly-1-propene	toluene
2,4-pentadione	butyl acetate
cyclopentanone	5-hexen-1-ol
xylene	2-heptanone
ethynylbenzene	* styrene
cyclohexanone	1,3-cyclopentanedione
1,1'-bicyclopropyl	(1-methylethenyl)-benzene
benzaldehyde	benzonitrile
2-propenylbenzene	3-butenylbenzene
2-propynylbenzene	.alpha.,.alpha.-dimethyl-benzenemethanol
1,3-diethenylbenzene	1,3-dimethyl-cis-cyclopentane
1-methyl-1H-Indene	1,2-dihydronaphthalene
* naphthalene	1-propene
ethane	ethene
acetylene	chromium
cadmium	

* Compounds listed as an Air Toxic per Clean Air Act Amendements of 1990.

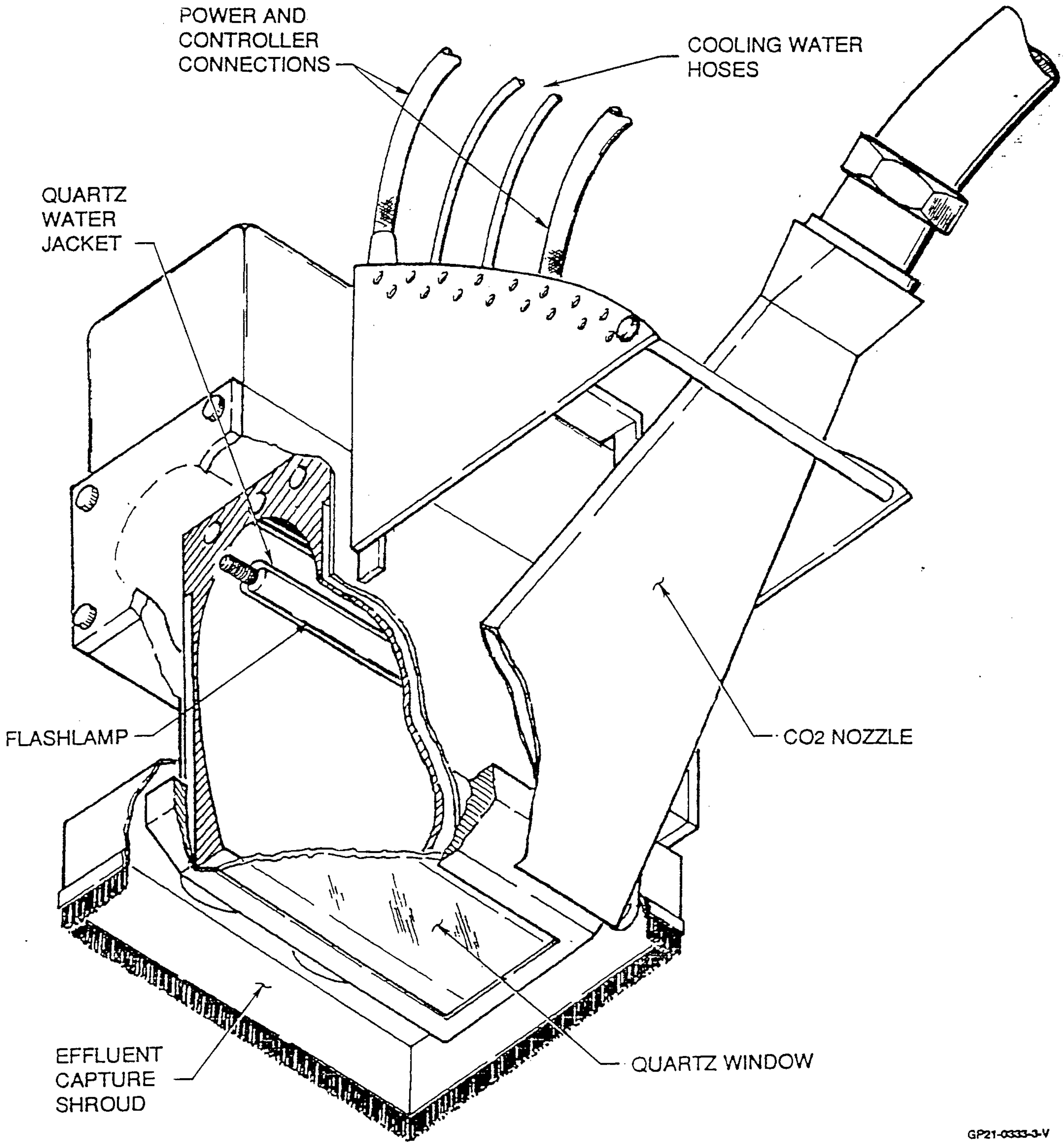

Figure 1. U.S.A.F. PRAM Project Prototype Stripping Head

WARNING

Make sure all electrical power is OFF before performing inspections.

a. Make sure electrical power is OFF.

WARNING

Isopropyl Alcohol is highly flammable and toxic. Do not use near open flame or sparks. Use only in well ventilated areas.

b. Using a clean cloth moistened with Isopropyl Alcohol, clean quartz window, Figure 1.

c. Visually inspect quartz window for cracks or crazing.

d. Visually inspect lamp for cracks, crazing or evidence of overheating.

e. Check all electrical connections for security.

f. Check water cooling lines for security and signs of leakage.

g. Check CO2 delivery hose for security and signs of damage.

h. Inspect motion/proximity sensing device as follows:

1) Check encoder wheel for freedom of rotation.

2) Check limit switch and arm for freedom of movement.

3.2.2 CCDS Power Supply.

Materials Required

None

WARNING

Make sure all electrical power is OFF before performing inspections.

Refer to Appendix A2, Section 2, Safety before opening doors.

a. Make sure electrical power is OFF.

b. Visually inspect cabinet for any obvious physical damage.

c. Visually inspect water cooling reservoir for proper water level.

d. Visually inspect B-Pure Cartridge resistivity GO/NO-GO indicators. Refer to Appendix A3, Operation, page 7.

3.2.3 Cold Jet Model 65-22.

Materials Required

None

WARNING

Make sure all electrical power is OFF before opening any panels or doors.

a. Make sure electrical power is OFF.

b. Visually inspect unit for any obvious physical damage.

c. Visually inspect electrical and hydraulic connections for security.

4.0 SYSTEM OPERATION.

4.1 **Stripping Head** - There are no operator requirements necessary for operation of the stripping head. The nozzle angle is pre-set for optimum stripping performance.

4.2 **Cold Jet Model 65-200** - The unit requires at least 30 minutes to compress liquid CO_2 into pellets at initial start-up. Refer to Appendix A4, SET-UP PROCEDURES, page 21. Set CO_2 pressure at 140 PSI. Set CO_2 feed at 40%.

4.3 **CCDS Power Supply** - After the 65-200 READY light comes ON, refer to Appendix A1, Section 4. OPERATING PROCEDURE and Appendix A2, Section 3. OPERATING INSTRUCTIONS. Set CCDS voltage to 1,600 with a rep rate of 3 Hz.

4.4 **Robotic Interface** - Follow customer furnished operating instructions for set-up and operation of the robot. Standoff distance between quartz window and surface is programmed to maintain 1.0 inch standoff. Strip traverse rate is programmed at 2 ft/min. The number of passes is dependent on film thickness.

4.5 **Flashlamp Life** - Lower operating voltage will increase lamp life. Voltage parameters are 0 to 1850v @ 4 Hz. 1850v maximum is limited by capacitor discharge capacity. While small voltage changes result in a major change in lamp life, major voltage changes will affect strip rates.

5.0 TECHNICAL MAINTENANCE.

5.1 This section describes Scheduled and Unscheduled Maintenance, Troubleshooting Procedures, and System Safety Interlocks associated with the PRAM Project 6-Inch Prototype Advanced Coatings Removal Process.

5.2 **Warranties** - The 6-Inch Stripping head and CCDS Power Supply are covered under warranties set forth by Maxwell Laboratories, Inc. Refer to Appendix A1, Section 6 WARRANTY SUMMARY. The Cold Jet Model 65-200 is covered under warranties set forth by Cold Jet , Inc. Refer to Appendix A4, WARRANTY COMPLIANCE. The B-Pure Pressure Cartridge System is covered by the warranty set forth by Barnstead/ Thermolyne. Refer to Appendix A3, WARRANTY.

5.3 **Scheduled Maintenance.**

5.3.1 Stripping Head Assembly - Scheduled maintenance of the stripping head assembly consists of daily inspections as outlined in paragraph 3.0 of this manual and periodic replacement of the flashlamp.

5.3.1.1 Flashlamp Replacement.

Materials Required

Part Number	Manufacturer
L7741	ILC Technology
QFX413	Q-Arc Limited

NOTE

Flashlamp service life is predicted to be 8 operating hours.

a. Refer to LAMP REPLACEMENT PROCEDURE, Appendix A1, Section 5.

5.3.1.2 Lamp Pre-Conditioning - Lamp life may be increased by pre- conditioning the cathode prior to running the lamp at full power. Pre-Conditioning consists of running the lamp @ ~ 1000v for 500 shots @ 4 pulses per second. After lamp replacement, pre-condition as follows:

a. Position stripping head such that the pulsed light energy output is at least 4 feet from any surrounding structure.

b. Disable motion/proximity sensor by disconnecting plug P6 on stripping head.

c. Connect wrap around jumper to plug P6.

d. Set voltage, number of shots, and pulse rate for pre-conditioning. Refer to Appendix A1, Section 4, paragraph 4.2.

e. Operate flashlamp. Refer to Appendix A1, Section 4, paragraph 4.3.

NOTE

Enable motion/proximity sensor upon completion of pre-conditioning.

f. Remove wrap around jumper from plug P6.

g. Reconnect cable from flashlamp controller to plug P6 on stripping head.

5.3.1.3 Quartz Window - No scheduled maintenance required. Refer to paragraph 5.4.1.1 for unscheduled maintenance.

5.3.1.4 Reflector - No scheduled maintenance required. Refer to paragraph 5.4.1.3 for unscheduled maintenance.

5.3.1.5 Proximity/Motion Sensor - No scheduled maintenance required. Refer to paragraph 5.6 System Safety Interlocks.

5.3.2 CCDS Power Supply - Scheduled maintenance of the CCDS Power Supply consists of daily inspections as outlined in paragraph 3.0 of this manual.

5.3.3 B-Pure Pressure Cartridge - Refer to Appendix A3, Maintenance and Servicing for scheduled maintenance procedures.

5.3.4 Cold Jet Model 65-200 - Refer to Appendix A4, PREVENTATIVE MAINT-ENANCE, for 25 hour, 100 hour, and 500 hour scheduled inspection requirements.

5.4 **Unscheduled Maintenance.**

5.4.1 Stripping Head Assembly - Unscheduled maintenance of the stripping head assembly consists of replacement of the quartz window, quartz water jacket, and reflector refurbishment.

5.4.1.1 Quartz Window - In the event the quartz window is damaged, crazed, or clouded, replace as follows:

Materials Required

Synthetic Fused Silica Window, dimensions 7.375 in X 3.0 in X 0.230-0.250 in thick, manufactured by Heraeus Amersil or Dunasil. Maxwell P/N 97525b1.

WARNING

Make sure all electrical power is OFF.

a. Make sure all electrical power is OFF.

b. Remove 20 screws (48), Maxwell drawing SK 97523, securing window clamp (13).

c. Remove clamp (13), window (6), and O-ring (41).

d. Install O-ring (41), window (6), and clamp (13).

e. Install 20 screws (48) secruing window clamp (13).

5.4.1.2 Quartz Water Jacket - In the event the water jacket is damaged, crazed, or clouded, replace as follows:

Materials Required

Quartz Water Jacket, dimensions 13mm ID, 15mm OD X 11.1 in long, manufactured by Heraeus Amersil. Maxwell P/N 97524b1.

WARNING

Make sure all electrical power is OFF.

a. Make sure all electrical power is OFF.

b. Remove flashlamp, refer to LAMP REPLACEMENT PROCEDURE, Appendix A1, Section 5.

c. Disassemble stripping head as required, refer to Maxwell drawing SK 97523.

d. Install water jacket.

e. Reassemble stripping head.

f. Reinstall flashlamp.

5.4.1.3 Reflector - In the event the reflector surface becomes degraded with age or use, contact Maxwell Laboratories, Inc. for engineering disposition.

5.4.2 CCDS Power Supply - All unscheduled maintenance requirements are outlined in the commercial manual. Refer to Appendix A2, Sections 3 and 4. System Safety Interlocks for the power supply are described in paragraph 5.6.

5.4.3 B-Pure Pressure Cartridge - All unscheduled maintenance requirements are outlined in the commercial manual. Refer to Appendix A3.

5.4.4 Cold Jet Model 65-200 - All unscheduled maintenance requirements are outlined in the commercial manual. Refer to Appendix A4.

5.5 **Troubleshooting.**

5.5.1 Stripping Head - Visually inspect for loose connections or obvious physical damage.

5.5.2 CCDS Power Supply - Refer to Appendix A2, Section 11, TROUBLESHOOTING GUIDE..

5.5.3 B-Pure Pressure Cartridge - Refer to Appendix A3, TROUBLESHOOTING GUIDE.

5.5.4 Cold Jet Model 65-200 - Refer to Appendix A4, TROUBLESHOOTING.

5.6 **System Safety Interlocks.**

5.6.1 Stripping Head -
The motion sensor interface is a small electronic circuit mounted on the stripping head. The circuit interacts with the stripping head control-WR robot controller, flashlamp controller-and sensors at the head in order to provide safety time-outs for the operation of the flashlamp. This interface monitors the motion of the stripping head with a wheel and encoder assembly mounted along the centerline of the flashlamp axis. The wheel and encoder assembly are spring loaded with a proximity switch to indicate that the wheels have come in contact with the surface. The interface provides a "Flashlamp Request" signal from the WR robot controller. Based on the conditions at the strip head, the interface either asserts a "Flashlamp Command" signal or leaves the "Flashlamp Command" signal inactive, thereby inhibiting flashlamp operation. The operating conditions at the strip head are wholly determined by the encoders and proximity switch as follows:

Flashlamp Request - Signal from robot controller indicating that the flashlamp should be turned on. When this signal is active, the interface will decide whether or not to turn on the flashlamp based on conditions at the strip head.

Flashlamp Command - Generated by the motion sensor interface in response to a "Flashlamp Request" if the proper operating conditions have been established. When this signal is active, the flashlamp will turn on.

Contact - Signal obtained from the strip head wheel assembly indicating that the wheels have contacted the surface (Proximity). Activation of this signal indicates contact has been made.

Motion - A conditioned signal from the encoders indicating that the strip head is moving. The amount of linear motion at the strip head that will activate this signal is jumper selectable at the motion sensor interface. When this signal is active, it indicates that motion is occuring.

NOTE

The motion direction is not detected. Motion in either fore or aft direction will permit flashlamp operation.

The following rules will be used to govern valid flashlamp operating conditions:

a) Flashlamp operation will only be permitted when "Flashlamp Request" signal is true.

b) The "Flashlamp Command" signal will be de-activated within 1 msec after "Flashlamp Request" is removed.

d) If the "Flashlamp Request" is active, "Motion" is detected, and "Contact" is active, the "Flashlamp Command" will be active.

e) If "Flashlamp Request" becomes active while "Contact" is active, the "Flashlamp Command" will become asserted for a period of time (T1) while no "Motion" is detected.

f) If the "Flashlamp Request" is active and "Contact" becomes active, the "Flashlamp Command" will be asserted for a period of time (T1) while "Motion" is active.

g) While the "Flashlamp Request" remains active and "Contact" is active, if "Motion" becomes inactive, the "Flashlamp Command" will be de-asserted after a period of time (T2).

h) If the "Flashlamp Request" is active, "Contact" is active, loss of "Motion" is detected and then becomes active, the "Flashlamp Command" will be re-asserted within 1 msec of the "Motion" signal.

i) If the "Flashlamp Request" is active, loss of "Motion" has been detected and "Contact" becomes inactive, the "Flashlamp Command" will be re-asserted.

NOTE

The "Motion" signal is a conditioned output from the encoder with selectable resolution. Motion less than the resolution will not be detected and not permit flashlamp operation. It is implicitly assumed "Motion" will not be active unless "Contact" is active.

5.6.1.1 Safety Circuit Timing and Adjustment.

The safety circuit consists of the following:

- 2" diameter wheels
- 1000 pulses per rev incremental encoders
- Encoder output at one foot per minute
  {(1 ft/min)*(12 in/ft)*(1000 pulses/rev)}/
  {(60 sec/min)*(2π in/rev)} = 31.8 Hz

a) Input RC filter eliminates high frequency noise and jitter - ($0.1\mu F$)*($15K\Omega$)=1.5mS or ~666 Hz. Maximum frequency passed (measured) was 435 or ~6.8 ft/min.

b) Input one shot eliminates low frequency noise and jitter - 0.33*($2.2\mu F$)*($50K\Omega$) = 36.6 mS or 27.5 Hz. Note that 50 $K\Omega$ is the maximum low frequency. This time has been pre-set to 30 mS.

c) Counter - Divides the pulses per revolution from both encoders prior to motion pulse generation. This counter sets the amount of physical motion required to cause a motion pulse to be generated. This counter is jumper selectable and has been pre-set to divide the incoming encoder pulses by 16 (jumper J11 installed.

d) Normalizing one shot-Produces a positive $125\mu S$ normalized pulse on the rising edge of each motion pulse. This pulse is not adjustable nor does it affect the timing of the safety circuit.

e) Stop time-out one-shot - Sets the time allowed from the rising edge of the last motion pulse until flash inhibit occurs. The maximum length of this time-out (measured) is 3.3 S; the minimum (measured) is 26 mS. The stop time-out has been pre-set to 0.5 S.

f) Start time-out one-shot - Sets the time allowed from the rising edge of the flash request while surface contact is true until the rising edge of the first motion pulse. If motion

rising edge of the first motion pulse. If motion does not occur within the start time-out period flash inhibit occurs. The maximum length of this time-out (measured) is 2.9 S; the minimum (measured) is 25 mS. The start time-out has been pre-set to 2.9 S.

MINIMUM SPEED:
The minimum speed target was one foot per minute. With both wheels in motion at one foot per minute, the combined output of the encoders is 63.6 Hz. The minimum (measured) frequency at which stop time-out did not occur was 40 Hz., or ~0.628 ft/min.

MAXIMUM SPEED:
The maximum speed target was eight feet per minute. With both wheels in motion at this rate, the combined output of the encoders is 509.3 Hz. Since the maximum passed frequency (measured) of the input RC filter is 345 Hz, the maximum speed is ~6.83 ft/min.

5.6.2 CCDS Power Supply - The CCDS power supply has several safety interlocks incorporated which will not allow the unit to operate until the interlock safety conditions are met. These interlocks include:

a) Water Flow Interlock

b) Water Level Interlock

c) Air Flow Interlock

d) Door Interlocks

e) Dump Interlocks

Upon system start-up, the "INTERLOCKS SATISFIED" light on the computer control panel will illuminate RED. Refer to Appendix A1, Section 4.3, OPERATION. If the "INTERLOCKS SATISFIED" light fails to illuminate, "click" on the "RESET

INTERLOCKS" button on the computer control screen. If the interlocks fail to reset, do the following:

5.6.2.1 Water Flow Interlock.

NOTE

The computer screen does not identify which interlock is not set.

a. Make sure hoses are not "kinked" or broken.

WARNING

Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED.

b. Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED. Refer to Appendix A1, Section 2. SAFETY.

c. Make sure hose connections at strip head and pump assembly are secure.

d. Inspect cooling system inside CDDS power supply cabinet for correct valve positions and any obvious physical damage.

e. Refer to Appendix A3, TROUBLESHOOTING GUIDE for possible problems and solutions.

5.6.2.2 Water Level Interlock.

NOTE

The computer screen does not identify which interlock is not set.

a. Make sure hoses are not broken.

WARNING

Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED.

b. Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED. Refer to Appendix A1, Section 2. SAFETY.

c. Make sure hose connections at strip head and pump assembly are secure.

d. Check for proper cooling water level in reservoir in CCDS power supply cabinet.

e. Refer to Appendix A3, TROUBLESHOOTING GUIDE for possible problems and solutions.

5.6.2.3 Air Flow Interlock.

NOTE

The computer screen does not identify which interlock is not set.

a. Check outside air flow exhaust areas for obstructions.

WARNING

Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED.

b. Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED. Refer to Appendix A1, Section 2. SAFETY.

c. Check cooling fan in CCDS power supply cabinet.

5.6.2.4 Door Interlocks.

Door interlocks are designed to prevent system operation if any doors other than the computer control door is open.

NOTE

The computer screen does not identify which interlock is not set.

a. Make sure doors are properly secured.

WARNING

Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED.

b. Make sure all electrical power is OFF and capacitors and inductors are DISCHARGED. Refer to Appendix A1, Section 2. SAFETY.

c. Open doors and inspect interlock switches for obvious physical damage and connections for security.

5.6.2.4 Dump Interlock.

The dump interlock is designed to automatically discharge the capacitors and inductors upon system shutdown. Failure of this interlock will not be readily apparent during system operation. Whenever any maintenance is performed or the power supply cabinet doors are opened, the procedures outlined in Appendix A1, Section 2. SAFETY must be followed.

5.6.3 B-Pure Pressure Cartridge System.

There are no safety interlock requirements associated with the cartridge filter system.

5.6.4 Cold Jet Model 65-200.

Safety circuits incorporated into the Cold Jet Model 65-200 unit include:

a) AUTOMATIC HYDRAULIC SYSTEM SAFETY SHUT-DOWNS. Refer to Appendix A4, page 43.

b) LIQUID INJECTION SYSTEM SHUT-DOWNS. Refer to Appendix A4, page 44.

c) MANUAL BLAST NOZZLE SYSTEM SHUT-DOWNS. Appendix A4, page 45.

6.0 **PARTS LISTS.**

6.1 **Stripping Head** - Parts list for the PRAM Project 6-Inch Stripping Head Assembly is included on the Maxwell drawing SK 97523.

6.1.1 Stripping Head Integration Hardware Parts integrating the CO_2 nozzle and sensor hardware to the stripping head are included on McDonnell Douglas drawing 91CST 0500.

6.2 **CCDS Power Supply** - For parts associated with the CCDS power supply cabinet, contact Maxwell Laboratories, Inc. at (619)-576-7573.

6.3 **B-Pure Pressure Cartridge System** - Cartridges, filters, and a complete illustrated parts breakdown are included in Appendix A3.

6.4 **Cold Jet Model 65-200** - Complete parts lists and illustrated parts breakdowns are included in Appendix A4.

Appendix A1
PRAM Six Inch Flashblast System Operation Manual (MLR-4047)

MLR-4047
SEPTEMBER 29, 1992

OPERATION MANUAL
FOR THE
PRAM PROJECT SIX INCH FLASHBLAST SYSTEM

Prepared by

Maxwell Laboratories, Inc.
8888 Balboa Avenue
San Diego, California 92123-1506

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SECTION 1
GENERAL DESCRIPTION

The PRAM Project Six Inch Flashblast System (PRAM FS) is a laboratory prototype for use in conjunction with a Cold Jet. Inc. CO2 pellet blasting system. The intended use of the integrated system is for paint removal. The PRAM FS consists of a flashlamp (lamp) module, a water cooling system, a high-voltage power supply (Maxwell CCDS), a power conditioning section and computer control system. The power conditioning section is comprised of the main energy storage capacitor bank, a solid-state switch assembly and trigger, and the pulse shaping inductor. All of the components, with the exception of the lamp module are contained within the main enclosure.

The main enclosure is divided into two major compartments and three minor, rear compartments. The left hand major compartment houses the controls, high-voltage power supply, lamp simmer power supply, and the AC power distribution. The right hand major compartment houses the power conditioning section and the AC power disconnect. The water cooling system is located in one of the minor, rear compartments.

The lamp module is located remotely, up to two hundred feet away. Connected to the lamp module is the main pulse cable, lamp module interlock cable (twisted pair with CPC connector), and a pair of cooling water lines (inlet/outlet). An additional, multiconductor cable is provided for interface to the McDonnell Douglas integration equipment.

Operation and maintenance manuals for the power supplies, the control computer, and the water cooling equipment are included in the Appendix.

SECTION 2
SAFETY

WARNING

THE HIGH VOLTAGE AND AC POWER USED IN THE PRAM FS MAY BE LETHAL. BEFORE WORKING WITH THIS EQUIPMENT OR COMPONENTS CONNECTED TO THE OUTPUT OF THE PRAM FS, MAKE SURE THE AC POWER TO THE PRAM FS IS OFF AND GROUND (DISCHARGE) ALL HIGH VOLTAGE CAPACITORS WITH THE APPROPRIATE GROUNDING DEVICE.

2.1 PERSONNEL SAFETY.

Maxwell Laboratories, Inc. (Maxwell) has made every effort to provide safety features to assure personnel safety in accordance with industry approved safety standards.

A high voltage grounding stick is supplied with the equipment. Figure 2.1 Discharge Locations shows the ground point and locations where a charge may exist within the enclosure.

WARNING

Failure to comply with the following procedure for safetying the high voltage power supply may result in injury of death.

Only qualified personnel are allowed to open the enclosure doors or panels.

2.1.1 Power Supply Enclosure Safetying-

WARNING

Make sure all electrical power is OFF before opening any doors or panels.

a. Make sure the MANUAL POWER SWITCH, Figure 2.1 Discharge Locations is OPEN.

b. Turn electrical power OFF at source.

WARNING

Do not bodily enter or touch any internal components within the main enclosure until grounding (DISCHARGE) procedure has been completed.

c. Open right hand door of main enclosure.

WARNING

Use only the Grounding Stick supplied with the equipment for the grounding (DISCHARGE) procedure.

Hold the plastic handle in one hand while keeping the free hand behind your back.

d. Connect the spring clip marked GROUND of the grounding stick to the GROUND BUSS located on the edge of the CAPACITOR BANK, Figure 2.1 Discharge Locations.

WARNING

To ensure total DISCHARGE, the grounding stick must maintain contact at the Discharge Locations for a minimum of 5 seconds.

e. While holding the plastic handle of the grounding stick in one hand and keeping the free hand behind your back, touch the grounding stick to the HIGH VOLTAGE BUSS on top of the CAPACITOR BANK for a minimum of 5 seconds, Figure 2.1 Discharge Locations.

WARNING

To ensure total DISCHARGE is maintained during maintenance, hang the grounding stick on one of the exposed INDUCTOR Conductors.

f. Hang the grounding stick on one of the exposed INDUCTOR Conductors, Figure 2.1 Discharge Locations.

CAUTION

Failure to remove grounding stick before resuming normal operations may result in damage to the power supply components.

g. Remove the grounding stick from the INDUCTOR Conductor.

h. Remove ground clip from GROUND BUSS.

CAUTION

Do not operate power supply without covers, panels, and mounting hardware as supplied properly installed.

NOTE

Door interlocks will not allow the unit to operate unless doors are properly secured.

i. Make sure doors, covers, and panels are properly closed and/or installed.

j. Close MANUAL POWER SWITCH and start system, refer to Section 4, OPERATING PROCEDURE.

NOTE

All service, other than procedures outlined in these manuals, should be performed by factory qualified personnel only.

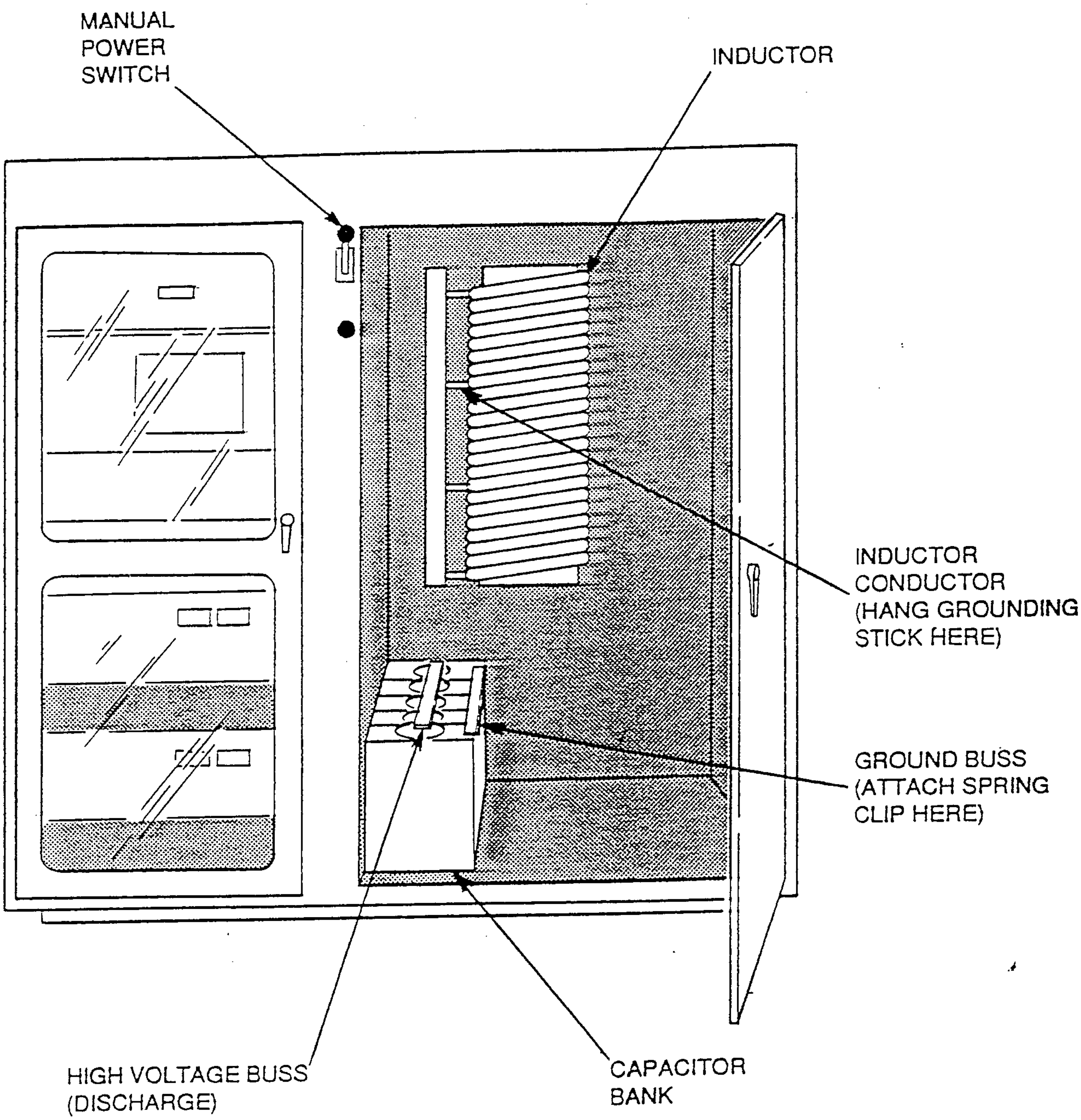

Figure 2.1 Discharge Locations

SECTION 3
INSTALLATION

WARNING

Improper connection of the PRAM FS interface may result in damage to the PRAM FS and endanger personnel safety.

3.1 AC POWER INPUT.

The AC power line input is routed through an access panel located on the back and near the top of the main enclosure. A two inch, liquid tight conduit connector is provided for this purpose. The AC power requirements are:

Voltage - 208 VAC, 3ø
Current - 100 Amps/ø

Four #2 AWG wires, three phases and a ground should be used. The three phases connect to the line side of the main disconnect switch and the ground should be routed to the chassis ground located on the capacitor bank.

3.2 LAMP MODULE COOLING WATER.

CAUTION

Operation of the water pump with the valves closed may result in damage to the pump.

The right rear minor compartment contains the circulator and deionizer for the lamp module cooling water. Remove the top and side access panels to set-up and service the water cooling system. Fill the reservoir with distilled water until the level is just above the level detector switch. Install a deionizing cartridge filter in the filter housing per the manufacturer's instructions, Appendix A3.

Connect the two 1/2 inch, polyethylene supply and return lines to the 1/2 inch bulkhead fittings on the rear of the PRAM FS enclosure. Replace the reservoir cover. Open all of the valves and replace the access panels.

3.3 REMOTE CONTROL PENDANT.

Connect the 9-pin CPC connector plug of the remote control pendant to the 9-pin CPC receptacle located on the lower, left side of the main enclosure.

3.4 COLD JET INTERFACE.

There is a 5-pin, threaded connector located on the lower, left side of the main enclosure for interface to the Cold Jet CO2 pellet blasting equipment.

3.5 LAMP MODULE.

- Connection of CPC connector for lamp module service interlock.
- Connection of high voltage pulse cable.
- Connection of cooling water lines.
- Mounting points on lamp module.

The lamp module is attached to the carriage assembly by six 1/4-20 bolts and nuts. To remove the module, the lamp housing must be removed by loosening the four knobbed screws located on the top of the module. With the lamp housing removed, the six nuts holding the upper half of the module to the carriage assembly can be accessed.

The lamp module is equipped with an interlock which discharges the high voltage capacitors if the lamp is removed for any reason. The interlock is connected to the power supply by inserting the 4-pin CPC connector into the mating receptacle located on the top of the lamp module.

The lamp housing must also be removed in order to remove or re-attach the high voltage cable coming from the power supply cabinet. Four flathead screws in the ends of the module can then be removed allowing access to the high voltage cable connections. The cable lengths are such that the cable can only be hooked up with the proper polarity.

Water lines are removed from the module by depressing the outer ring of the quick disconnect fittings and pulling the fitting halves apart. To reassemble, the fittings must be pushed together until a "click" is heard.

SECTION 4
OPERATING PROCEDURE

Following the installation procedure outlined in Section 3, the PRAM FS is ready for operation as prescribed in the following operating procedure:

4.1 POWER ON AND SYSTEM SHUTDOWN.

CAUTION

With power on the power cord, the line side of the switch itself is energized even though the switch is open.

The manual switch, the handle of which is on the front of the enclosure, is an internal disconnect for the power cord. This switch must be closed as the first step in the power up procedure and opened in the last step of the power down procedure. It may also be opened, in emergency situations, to remove power from the enclosure.

4.2 CONTROL COMPUTER SCREEN.

The computer screen control panel is shown in figure 4.1 Computer Control Screen. All of the control and monitoring functions are included on this panel. The controls on the screen control panel may be "operated" using the mouse. Simply move the mouse until the cursor on the screen appears over any particular control. Then, click the mouse or hold the button down and move the mouse at the same time. This first mouse operation is referred to as a "click" and the second, a "drag". All screen control panel buttons are operated by "clicking" and the HIGH VOLTAGE SUPPLY VOLTAGE SETTING dial control is operated by placing the cursor on the red indicator on the dial and "dragging" it in a clockwise or counterclockwise direction. The values in the numerical controls, such as NUMBER OF FLASHES IN BURST may be changed by "dragging" across the number until its background color changes and then typing in the desired number from the keyboard, or by "clicking" on the small triangles located to the left to increase or decrease the value.

4.3 OPERATION.

The following operating procedure should be performed only after all preliminary safety procedures are accomplished:

1. Close the disconnect switch.

2. Press the button marked with a "<" and located at the top left of the computer keyboard. This "boots" the computer.

3. Wait until the computer is finished "booting".

4. Double "click" on the hard disk icon in the upper right hand corner of the screen.

5. Double "click" on the 6" PRAM folder, located in the screen window opened in the previous step.

6. Double "click" on the file labeled "Opening Panel".

7. Wait approximately one minute until the screen control panel appears. The controls may now be operated and the unit will respond.

8. The unit is shut down by "clicking" on the COMPUTER OFF button. After a short delay, this operation will leave another screen which allows the control screen to be reactivated by "clicking" on the arrow, as instructed or by starting the computer shutdown procedure by selecting **Quit** from

the **File** Menu. If you elect to shut down the computer, wait a minute after selecting **Quit** until screen activity stops and then select **Shut Down** from the **Special** Menu. After a few seconds the computer will shut itself off.

OPERATION OF THE 6" PRAM UNIT FROM THE SCREEN CONTROL PANEL IS AS FOLLOWS:

1. "Click" the RESET INTERLOCKS button. This should cause the main contactor to close (audible click) and the INTERLOCKS SATISFIED and CONTACTOR indicators, below the RESET INTERLOCKS and COMPUTER OFF buttons, will change to a RED background after approximately 4 seconds. During this time the unit is turning on the cooling water and making sure flow is established.

2. "Click" the SIMMER SUPPLY ON button. After 4 seconds the SIMMER "OK" indicator light comes on indicating that the lamp is simmering. To stop simmering, "click" the SIMMER SUPPLY OFF button.

3. Select either BURST or CONTINUOUS by "clicking" on the white button marked as such in the LAMP CONTROL SETTINGS box.

4. Select the FLASH FREQUENCY values and NUMBER OF FLASHES IN BURST, if applicable.

5. "Click" RUN. After a 5 second delay, during which time the CO_2 is turned on, the flashing will commence and the RUNNING light will flash.

6. "Clicking" the STOP button causes the unit to stop flashing. After the flashing is stopped, another run can be made by repeating steps 4 and 5.

7. The RUN and STOP commands may also be made by pressing the appropriate buttons on the control pendant.

8. The EMERGENCY OFF button on the control pendant causes everything in the unit to shutdown, except for the computer and the disconnect switch. A second EMERGENCY OFF button is located on the front of the enclosure directly below the Disconnect Switch handle. Function of this button is the same as the control pendant button.

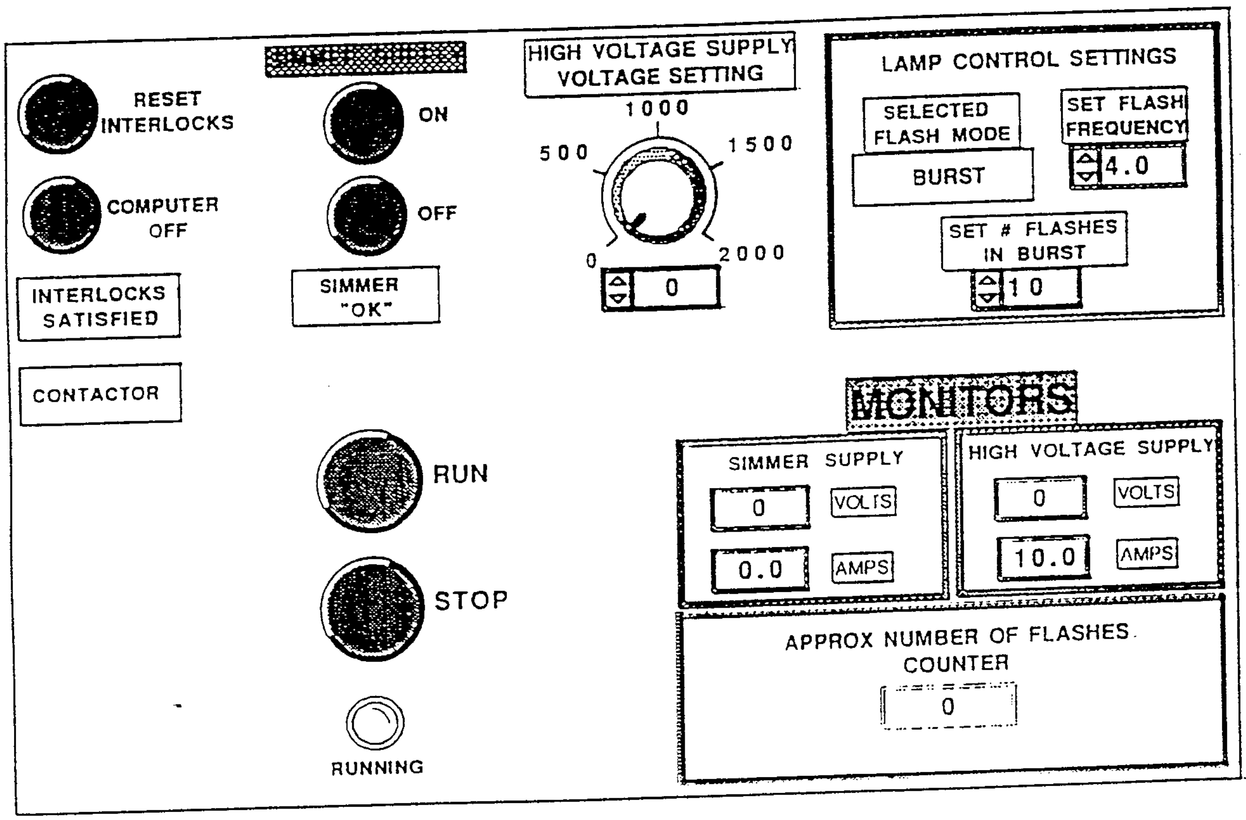

Figure 4.1 Computer Control Screen

SECTION 5
LAMP REPLACEMENT PROCEDURE

5.1 LAMP REMOVAL.

WARNING

Make sure electrical power is OFF.

a. Make sure electrical power is OFF and system is safetied. Refer to Section 2. SAFETY.

b. Disconnect water cooling lines. Refer to Section 3, paragraph 3.5 Lamp Module.

NOTE

Small bore under cover plate is ANODE side. Large bore under cover plate is CATHODE.

A small amount of water will leak from the housing when cover plates are removed. Make provisions to catch water.

c. Remove four screws securing Anode (+) coverplate, Figure 5.1.

d. Remove four screws securing Cathode (-) coverplate.

CAUTION

Any torque applied to the lamp during removal will likely break the quartz tube.

e. Using the 90 degree wrench provided, hold INBOARD 1/4-20 NUT and remove OUTBOARD 1/4-20 NUT and washer from Anode end of lamp.

f. Remove 1/4-20 CAPSCREW and washer securing CATHODE TERMINAL to housing.

g. Slide lamp, CATHODE TERMINAL, and INBOARD NUTS, as an assembly, out of housing.

h. Hold INBOARD 1/4-20 NUT and remove OUTBOARD 1/4-20 NUT, washer, and CATHODE TERMINAL from lamp.

i. Remove INBOARD 1/4-20 NUTS from both Anode and Cathode ends of lamp.

5.2 LAMP INSTALLATION.

a. Install INBOARD 1/4-20 NUTS on both Anode and Cathode ends of lamp.

CAUTION

To ensure that the longest lamp life is achieved, make sure that Cathode (-) and Anode (+) ends of lamp are connected to their respective terminals

NOTE

Standard cathode/anode markings are Cathode (-) BLACK and Anode (+) RED, unless otherwise indicated on shipping carton.

b. Install CATHODE TERMINAL, washer, and OUTBOARD 1/4-20 NUT on Cathode end of lamp.

NOTE

Small bore under coverplate is Anode side. Large bore under coverplate is Cathode.

c. Carefully slide lamp and terminal assembly into quartz water jacket in Cathode end of housing.

d. Install 1/4-20 CAPSCREW and washer securing CATHODE TERMINAL to housing.

e. Install COVERPLATE, O-RING, and four SCREWS securing coverplate to housing.

CAUTION

Any torque applied to lamp during installation will likely break quartz tube.

f. Install OUTBOARD 1/4-20 NUT and washer, HABDTIGHT, securing ANODE TERMINAL to lamp.

g. Using 90 degree wrench, hold INBOARD NUT and tighten OUTBOARD NUT.

h. Install COVERPLATE, O-RING, and four SCREWS securing coverplate to housing.

i. Reconnect water cooling lines.

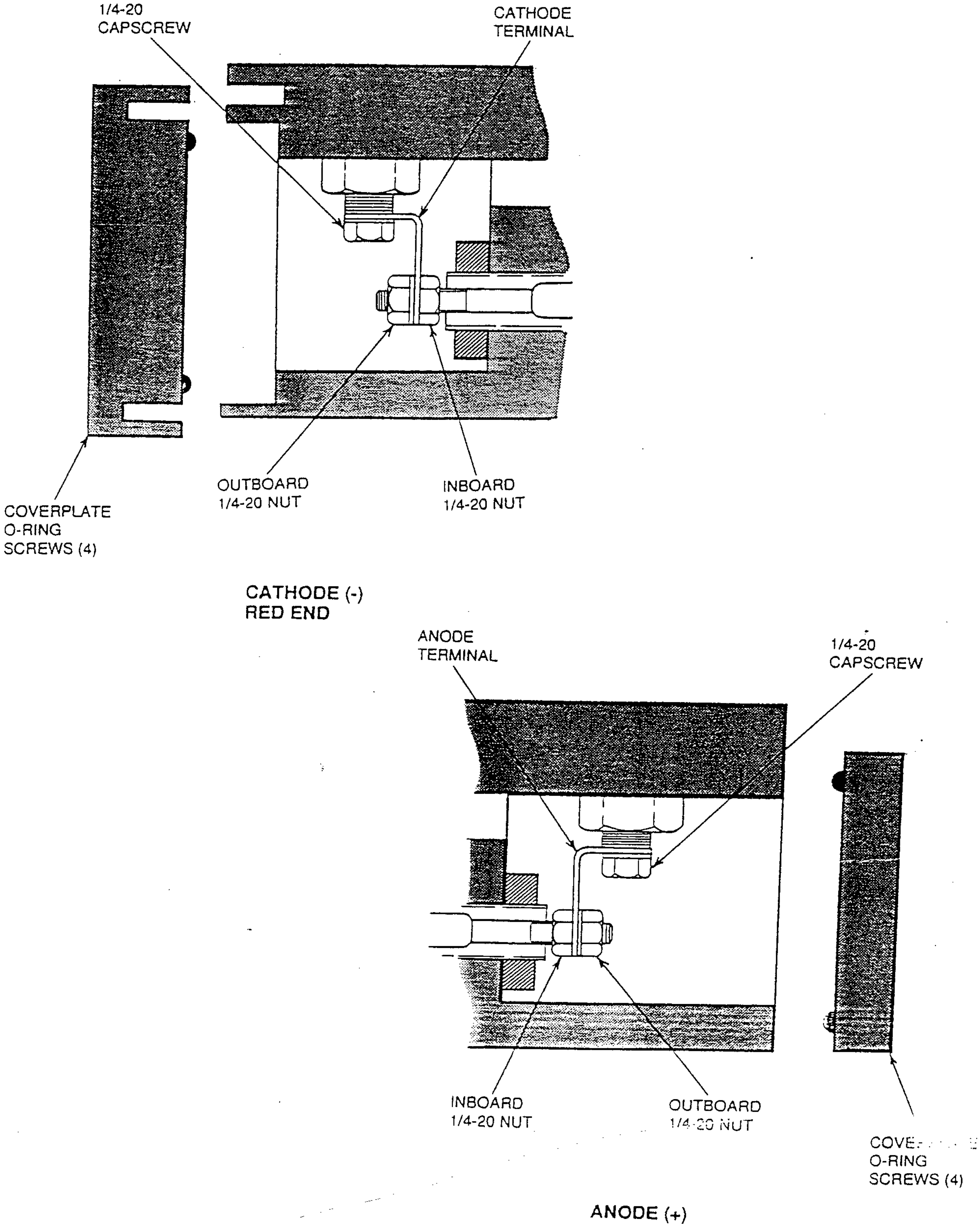

Figure 5.1 6-Inch PRAM Prototype Flashlamp Removal and Installation

Appendix A2
CCDS Power Supply
CCDS-802-336
(MLR-3700)

MLR-3700
December 1990

OPERATIONS AND MAINTENANCE MANUAL
FOR
CCDS POWER SUPPLY

Prepared by

Maxwell Laboratories, Inc.
Balboa Division
8888 Balboa Avenue
San Diego, California 92123-1506

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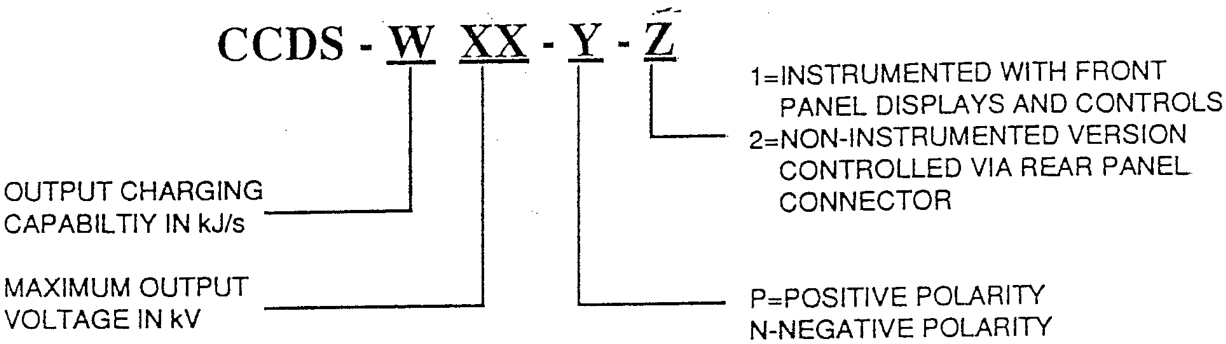
SECTION 1
GENERAL DESCRIPTION

The CCDS series is a high efficiency, capacitor charging power supply line that utilizes a high frequency series resonant inverter topology. All CCDS power supplies are designed to meet UL, CSA and IEC safety standards. The supply is packaged in a 8.75 in. tall, 19 in. wide rack mount chassis and weighs approximately 55 pounds. The input power is 3ø, 208 VAC, with a neutral. The power supply is specifically designed for constant current capacitor charging. Output voltage regulation is maintained to better than 0.1 percent for load rep-rates up to 2kHz. The supply efficiency is greater than 90 percent, with a power factor of approximately 85 percent. Overcurrent protection is inherent in the series resonant topology and fast overvoltage protection (OVP) is incorporated to prevent power supply damage in the event of an open-circuit load connection. Overtemperature protection is provided to prevent potential power supply failure in excessive ambient environments. Inrush current limit is also included to prevent surges on the user power grid during initial power supply turn-on. In addition, the supply has an internal delay after discharge which inhibits the HV output for approximately 100 µs after the load capacitor is discharged to allow the high voltage switch (e.g. thyratron) time to recover.

The power supply can be controlled either from the front panel local controls (instrumented version) or via the rear panel remote control interface. The local controls consist of control power ON/OFF, HV ON/OFF, output voltage programming, and digital voltage and current meters. The standard remote control interface includes HV ON/OFF, voltage and current monitor analog outputs, TTL HV INHIBIT, TTL HV ON indicator, end-of-charge (EOC) signal, remote voltage programming and voltage reference for resistive voltage programming.

The standard units are available in instrumented or non-instrumented versions, the only difference being front panel controls and digital displays of the instrumented version. Either version is fully controllable via the 15-pin remote control connector on the rear of the supply. The standard power supply is forced air cooled via a fan mounted in the rear panel.

The CCDS-WXX-Y-Z series of high voltage power supplies consists of models with characteristics keyed to the model number as shown in Figure 1-1. The "W" in the model number indicates the output charging rate (e.g., a CCDS-5XX is capable of delivering 5,000 J/s). The XX in the model number indicates the maximum high voltage rating (e.g., a CCDS-W25 operates between 0 and 25,000 V). The "Y" in the model number indicates the polarity; P for positive or N for negative. The "Z" in the model number indicates the version; 1 for instrumented or 2 non-instrumented.



MLG-32035

Figure 1-1. Model Number Nomenclature

Electrical Specifications.

Output Voltage (maximum)		2 kJ/s	4 kJ/s	6 kJ/s	8 kJ/s
	50 kV	CCDS-250	CCDS-450	CCDS-650	CCDS-850
	40 kV	CCDS-240	CCDS-440	CCDS-640	CCDS-840
	35 kV	CCDS-235	CCDS-435	CCDS-635	CCDS-835
	30 kV	CCDS-230	CCDS-430	CCDS-630	CCDS-830
	20 kV	CCDS-220	CCDS-420	CCDS-620	CCDS-820
	15 kV	CCDS-215	CCDS-415	CCDS-615	CCDS-815
	10 kV	CCDS-210	CCDS-410	CCDS-610	CCDS-810
	5 kV	CCDS-205	CCDS-405	CCDS-605	CCDS-805
	1 kV	CCDS-201	CCDS-401	CCDS-601	CCDS-801
Input Current (Steady State)	A/ø	8	16	24	32
AC Inrush Current (maximum)	A/ø	8	8	8	8

Input Voltage .... 208 VAC ± 10 percent, 3ø, 50/60 Hz.

Polarity .... Positive or Negative. Refer to model number on rear panel.

Efficiency .... > 90 percent.

Regulation .... 0.1 percent for 2 kHz rep-rate or less.

Protection .... Overcurrent / Overtemperature / Overvoltage.

Remote Control .... HV ON/OFF, voltage and current monitors, HV INHIBIT, voltage programming, EOC, HV ON indicator, voltage reference and REMOTE ENABLE.

Mechanical Specifications.

Size .... 8.75 in. high X 21 in. deep X 19 in. wide standard rack mount.
Weight .... 55 pounds
Cooling .... Forced air with internal fan.
Operating Temperature .... 0 to 45 degrees C.
Humidity .... 10 to 80 percent, non-condensing.

SECTION 2
SAFETY

WARNING

THE HIGH VOLTAGE AND AC POWER USED IN THE PRAM FS MAY BE LETHAL. BEFORE WORKING WITH THIS EQUIPMENT OR COMPONENTS CONNECTED TO THE OUTPUT OF THE PRAM FS, MAKE SURE THE AC POWER TO THE PRAM FS IS OFF AND GROUND (DISCHARGE) ALL HIGH VOLTAGE CAPACITORS WITH THE APPROPRIATE GROUNDING DEVICE.

2.1 PERSONNEL SAFETY.

Maxwell Laboratories, Inc. (Maxwell) has made every effort to provide safety features to assure personnel safety in accordance with industry approved safety standards.

A high voltage grounding stick is supplied with the equipment. Figure 2.1 Discharge Locations shows the ground point and locations where a charge may exist within the enclosure.

WARNING

Failure to comply with the following procedure for safetying the high voltage power supply may result in injury of death.

Only qualified personnel are allowed to open the enclosure doors or panels.

2.1.1 Power Supply Enclosure Safetying-

WARNING

Make sure all electrical power is OFF before opening any doors or panels.

a. Make sure the MANUAL POWER SWITCH, Figure 2.1 Discharge Locations is OPEN.

b. Turn electrical power OFF at source.

WARNING

Do not bodily enter or touch any internal components within the main enclosure until grounding (DISCHARGE) procedure has been completed.

c. Open right hand door of main enclosure.

WARNING

Use only the Grounding Stick supplied with the equipment for the grounding (DISCHARGE) procedure.

Hold the plastic handle in one hand while keeping the free hand behind your back.

d. Connect the spring clip marked GROUND of the grounding stick to the GROUND BUSS located on the edge of the CAPACITOR BANK, Figure 2.1 Discharge Locations.

WARNING

To ensure total DISCHARGE, the grounding stick must maintain contact at the Discharge Locations for a minimum of 5 seconds.

e. While holding the plastic handle of the grounding stick in one hand and keeping the free hand behind your back, touch the grounding stick to the HIGH VOLTAGE BUSS on top of the CAPACITOR BANK for a minimum of 5 seconds, Figure 2.1 Discharge Locations.

WARNING

To ensure total DISCHARGE is maintained during maint-enance, hang the grounding stick on one of the exposed INDUCTOR Conductors.

f. Hang the grounding stick on one of the exposed INDUCTOR Conductors, Figure 2.1 Discharge Locations.

CAUTION

Failure to remove grounding stick before resuming normal operations may result in damage to the power supply components.

g. Remove the grounding stick from the INDUCTOR Conductor.

h. Remove ground clip from GROUND BUSS.

CAUTION

Do not operate power supply without covers, panels, and mounting hardware as supplied properly installed.

NOTE

Door interlocks will not allow the unit to operate unless doors are properly secured.

i. Make sure doors, covers, and panels are properly closed and/or installed.

j. Close MANUAL POWER SWITCH and start system, refer to Section 4, OPERATING PROCEDURE.

NOTE

All service, other than procedures outlined in these manuals, should be performed by factory qualified personnel only.

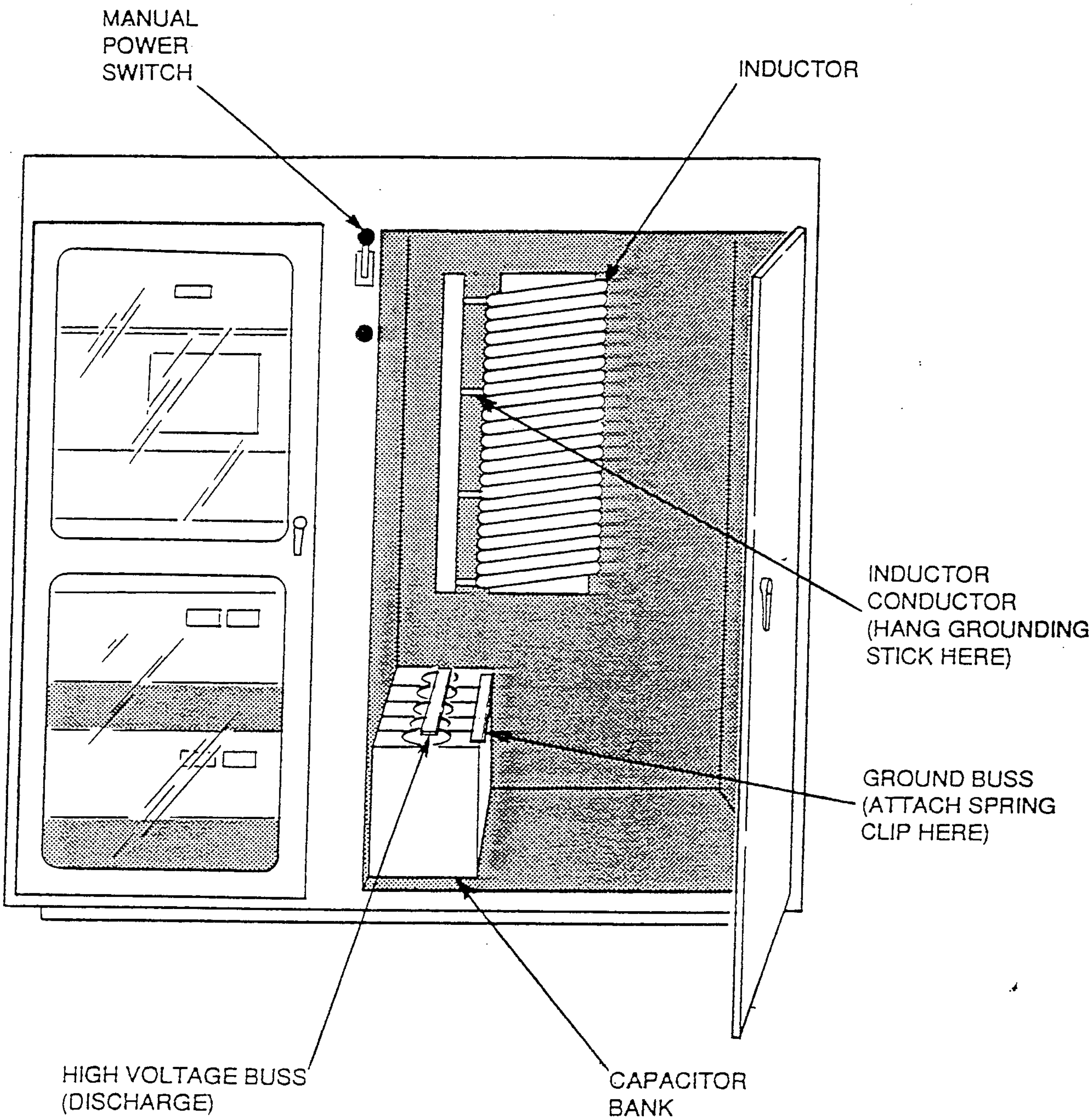


Figure 2.1 Discharge Locations

SECTION 3-
OPERATING INSTRUCTIONS

Instrumented models can be locally controlled from the front panel of the high voltage power supply. All models, whether instrumented or non-instrumented, can be fully controlled remotely via the remote control connector located on the rear panel of the unit.

3.1 Local Control.

Local control of a fully instrumented power supply is achieved via the front panel controls shown in Figure 3-1. CCDS High Voltage Power Supply Front Panel. Unless the REMOTE CONTROL ENABLE is activated, the remote control functions of the power supply are always disabled to provide maximum operator and personnel safety.

3.1.1 Control Power ON/OFF

Push the Control Power switch to turn ON the power supply control power. Assuming the external interlock is satisfied and the power supply internal fault protection interlocks are satisfied, the power supply is ready to produce the high voltage output.

NOTE

Prior to activating the high voltage output, be sure the output of the supply is connected to the load capacitor and the desired output voltage level is set via the Voltage Programming knob.

3.1.2 Voltage Programming

Turn the Voltage Programming knob to the desired percentage of the rated output voltage.

3.1.3 HV ON.

To activate the high voltage output, push the HV ON switch.

3.1.4 HV OFF.

To deactivate the high voltage output, push the HV OFF switch.

3.1.5 Voltage and Current Monitors.

The output voltage and the average output current is displayed on the front panel of the instrumented units using 3.5 digit LCD displays.

3.2 Remote Control.

The standard user controls and monitor interfaces for the power supply are available through the remote control connector, J201, located on the rear panel as shown in Figure 3-2. CCDS High Voltage Power Supply Rear Panel. A summary of the remote control interface is shown in Table 3-1. Remote Control Interface. A detailed description of each function follows:

3.2.1 Remote Control Enable.

To use remote voltage programming and remote HV ON/OFF, the REMOTE CONTROL ENABLE, Pin 8 must be connected to GROUND, Pin 15. In instrumented versions, this will disable the front panel voltage programming control, thus preventing a remotely controlled unit from being accidentally misadjusted from the front panel. For maximum operator and personnel safety, the front panel HV OFF and voltage and current displays are operational, regardless of the status of the REMOTE CONTROL ENABLE Pin.

3.2.2 Voltage Programming.

The desired output voltage can be set by an external input on Pin 12 of the remote control connector. An external input of 0 to 10 V on Pin 12 programs the output voltage from 0 to 100 percent.

NOTE

Remote HV programming requires activating the remote control enable by connecting Pins 8 and 15. This configuration will allow HV ON and HV OFF activation from both the front panel and remote controls.

3.2.3 High Voltage ON/OFF.

Remote HV ON requires a momentary contact closure between Pins 2 and 4.

NOTE

Remote HV ON operation requires activating the remote control enable by connecting Pins 8 and 15.

A momentary opening of Pins 1 and 3 activates the HV OFF.

NOTE

Pins 1 and 3 must be closed prior to the momentary closure of Pins 2 and 4 to turn the HV ON.

3.2.4 HV Inhibit.

A TTL compatible, HV INHIBIT input is provided to rapidly disable the inverter when the HV ON is in the activated state. This allows for a fast termination of a charging cycle or external logic controlled charging periods. A TTL "1" state at Pin 7 inhibits the high voltage output, while a TTL "0" (or open connection) allows for normal output operation via the HV ON/OFF controls. The HV INHIBIT input pin is referenced to digital ground, Pin 15.

3.2.5 Voltage Reference.

A buffered precision +10 V reference output is provided on Pin 10 of the remote connector for use with the remote voltage programming input. The voltage reference is referenced to the analog ground, Pin 11.

3.2.6 End of Charge.

CAUTION

The maximum voltage to be applied to Pin 13 through a pull-up resistor is 24 VDC. The pull-up resistor should limit the current to less than 25 mA.

An open collector output is provided on Pin 13 that is in a TTL "0" state, i.e., the collector is low when the supply is in the charging mode. The collector goes open circuit (external pull-up is required for logic "1" state) when the preset charge voltage is reached and the supply switches to the "keep alive" mode. This signals the EOC and tells the remote user the load capacitor is charged to the programmed voltage and is awaiting discharge into the load. The collector will remain in the open state as long as the load capacitor voltage is at the programmed voltage level. This output is referenced to digital ground, Pin 15.

3.2.7 Voltage Monitor.

A 0 to 10 V output signal located on Pin 5 of the remote control connector provides a linear analog monitor of the power supply output voltage corresponding to 0 to 100 percent of the rated output voltage. This output signal is referenced to analog ground, Pin 11.

3.2.8 Current Monitor.

An analog current monitor of the power supply's average output current is located on Pin 6 of the remote control connector. The current monitor voltage output is normally calibrated to 10 mV/mA. The analog current monitor output is referenced to analog groung, Pin 11.

3.2.9 HV ON Indicator.

Pin 14 of the remote control connector is a TTL HV ON indicator. The voltage on Pin 14 will be greater than 4 V when the power supply is in the HV ON state. It will be less than 0.6 V when the power supply is in the HV OFF state. Also, this signal can be used as a fault indicator since it will go to the HV OFF state if there is any unexpected fault in the supply.

3.3 External Interlock.

CAUTION

The voltage appearing on the external internal terminals is 24 VDC. Connections to these terminals must be done with isolated contacts to prevent potential damage to the power supply controls.

An external safety interlock option is provided by TB201 on the rear panel. Terminals 1 and 2 must be connected with isolated contacts to allow the power suppy to be activated. When using multiple interlocks, it is recommended the isolated contacts of each be connected in series. This can be utilized as a safety switch to disable the power supply HV output in the event of an external fault condition. An open circuit between terminals 1 and 2 will inhibit the high voltage output under any condition.

3.4 AC Input Connections.

WARNING

This connection must be made to assure maximum personnel safety.

The 208 VAC, 3ø power connections are made to TB1 located on the rear panel. The ground wire should be connected to the chassis ground screw terminal located under TB1.

WARNING

As with the majority of commercial power supplies and pieces of laboratory electronic equipment today, the input filter capacitors remain charged as long as the circuit breaker, CB1, is on and the unit is connected to the power line. This is independent of the position of the control power ON/OFF switch of an instrumented unit.

The 3ø input cable should be sized to handle the maximum input current stated in the electrical specifications section of this manual. The standard power supply is provided with an internal 3ø circuit breaker, CB1, located on the rear panel.

Carefully read Section 5 prior to removing the top cover of the power supply.

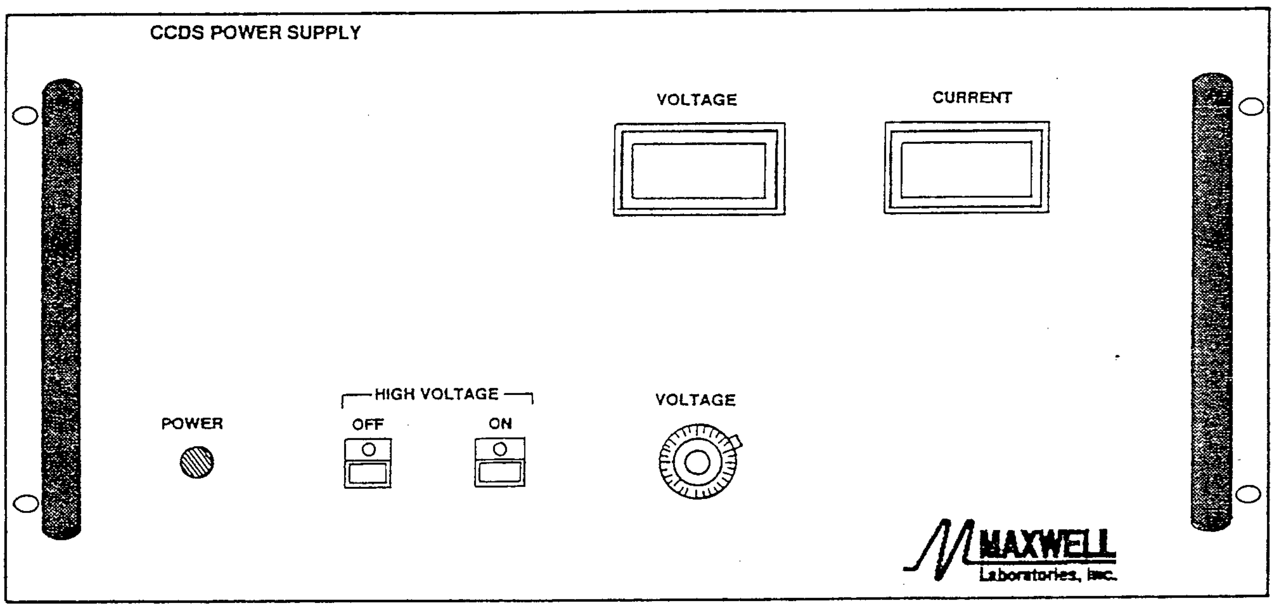
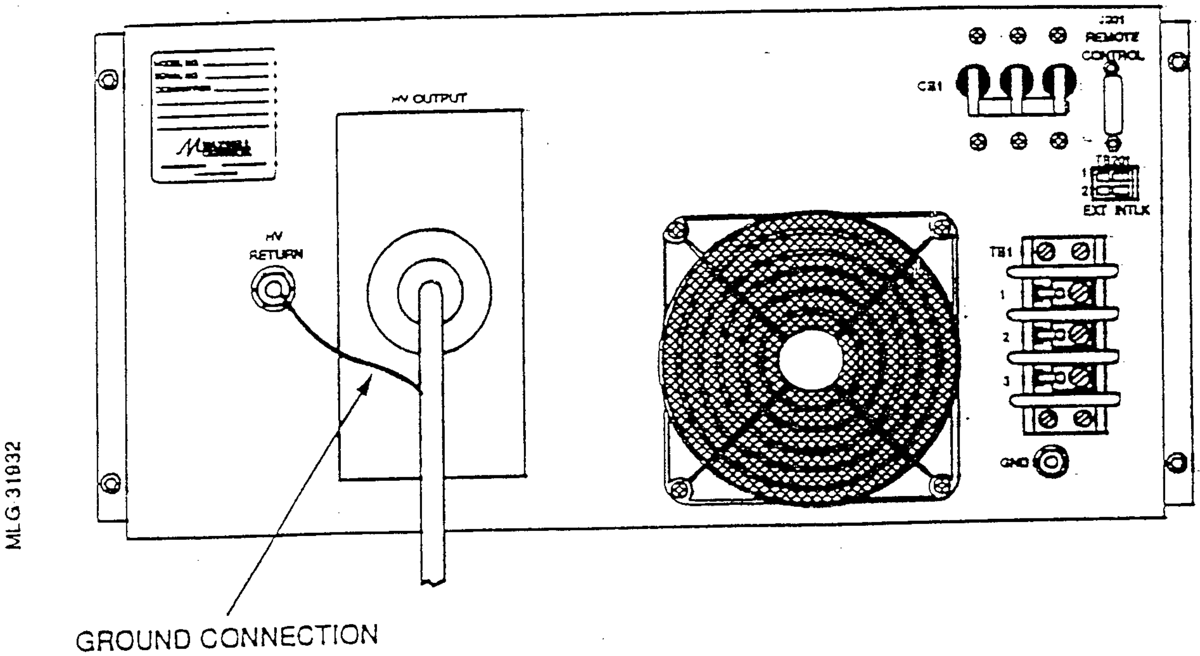
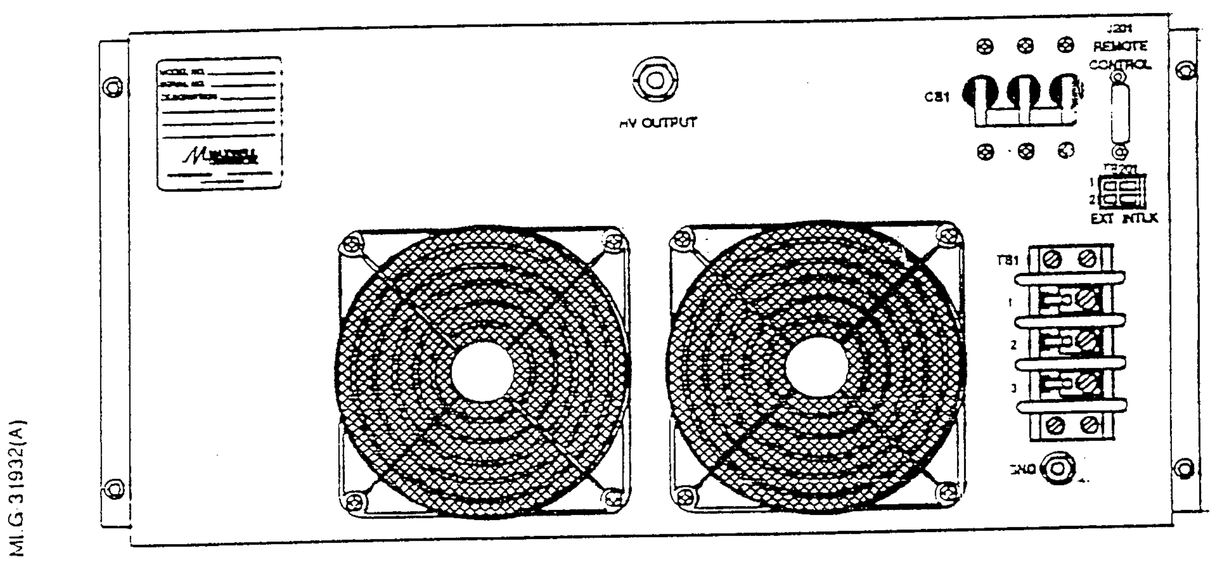


Figure 3-1. CCDS High Voltage Power Supply Front Panel



(A) OIL INSULATED MODELS



(B) AIR INSULATED MODELS

Figure 3-2. CCDS High Voltage Power Supply Rear Panel

Table 3-1. Remote Control Interface

PIN NUMBER	DESCRIPTION
2 , 4	HV ON: Normally open, momentarily short to turn HV ON.
1 , 3	HV OFF: Normally closed, open to turn HV OFF.
13	EOC: Open collector output, open at EOC.
14	HV ON Indicator: TTL high indicates HV ON; HVPS okay.
10	+10V reference for resistive voltage programming (10mA max.)
12	Voltage Programming: 0 to 10 V for 0 to 100% output voltage.
5	Voltage Monitor: 0 to +10 V for 0 to 100% output voltage.
6	Current Monitor: 10mV/mA for 0 to 100% output current typical.
7	HV Inhibit: TTL high inhibits HV output.
8	Remote Enable: Ground to enable remote control.
11,15	Ground for control signals.
9	Unused

SECTION 4
FUNCTIONAL DESCRIPTION

The Power Supply Block Diagram is shown in Figure 4-1. The AC input section includes a 3ø circuit breaker, common/differential mode EMI filter, an inrush surge limit circuit, and the 3ø line rectifier and filter capacitors. The switching power converter utilizes a series resonant "H" bridge topology which drives the primary of a multi-secondary high frequency step-up transformer. Multiple, full-wave bridge, high voltage rectifier circuits produce the rectified high voltage output. The control circuit utilizes a fixed frequency, quasi-pulse width modulated scheme to drive the power converter. All user controls are buffered and interface with the control circuit directly. The following is a detailed description of the functions of each element in the block diagram.

4.1 INPUT EMI FILTER.

The 3ø input EMI filter attenuates both common mode (lines-to-chassis) and differential mode (line-to-line) high frequency noise. This includes conducted EMI, i.e., RF noise generated internally by the power supply inverter circuit and externally generated noise which may enter the power supply on the power lines. The filter is composed of a 3ø balun inductor with "X" (line-to-line) and "Y" (line-to-ground) capacitors placed symmetrically on both sides of the inductor. The filter has a common mode attenuation of better than 40 dB at 1 MHz and above.

4.2 INRUSH CURRENT LIMIT.

WARNING

As with the majority of commercial power supplies and pieces of laboratory electronic equipment today, the input filter capacitors remain charged as long as the circuit breaker is on and the unit is connected to the power line. This is independent of the position of the control power ON/OFF switch.

The inrush current limit circuit prevents high inrush surge currents during the charging of the input capacitors when the circuit breaker is initally turned on. The input capacitors are initially charged through a thermistor which limits the inrush charging current to a maximum of 16 A. The thermistor has a negative temperature coefficient. In the event of a short in the circuit after the thermistor, the thermistor resistance will drop to a sufficiently low value to cause the circuit breaker to trip. When the HV ON circuit is activated to start a charging cycle and the inverter turns on, an SCR fires that bypasses the inrush limiting thermistor, thus connecting the input capacitors directly to the input rectifiers during inverter operation.

Carefully read Section 5 prior to removing the power supply top cover.

4.3 SERIES RESONANT INVERTER.

The power converter utilized in the CCDS power supply is a series resonant "H" bridge topology operating in the 40 kHz range. This particular converter topology is ideal for high power, capacitor charging applications since it reflects a high source impedance to the output; consequently, this topology is inherently short circuit proof. The output characteristics of the inverter topology combined with the CCDS control topology result in a constant current (linear) charging profile.

The H-bridge switch elements are comprised of parallel power MOSFET transistors (FETs) or insulated gate bipolar transistor (IGBTs). The characteristics of these devices provide reliable high voltage, high current capability and easy device paralleling and control. When used as switches in a series resonant configuration as described above, the devices can be made to switch at zero current because of the sine wave property of the current in the LC circuit. As a consequence, the switching transistors have zero switching losses as compared to conventional pulse width modulated, quasi-square wave converter topologies.

4.4 HIGH VOLTAGE OUTPUT CIRCUITRY.

A multiple secondary high voltage transformer is used to step up the inverter voltage to the required output voltage. Multiple high voltage secondary windings are used to reduce the effects of parasitic resonances caused by secondary inductance and self-capacitance and to simplify the diode assemblies. Each winding is full-wave rectified by a high voltage diode bridge configuration. The rectifier circuits are then connected in series to sum the rectified voltage levels to the final output level.

The high voltage power transformer and entire high voltage output section (on 10 kV and higher supplies) is contained in a sealed, dielectric oil filled tank with oil-tight feedthroughs for all input/output lines. By paying careful attention to design stresses and using Maxwell's extensive capacitor impregnation knowledge base, oil insulation will assure maximum long term reliability of the high voltage section.

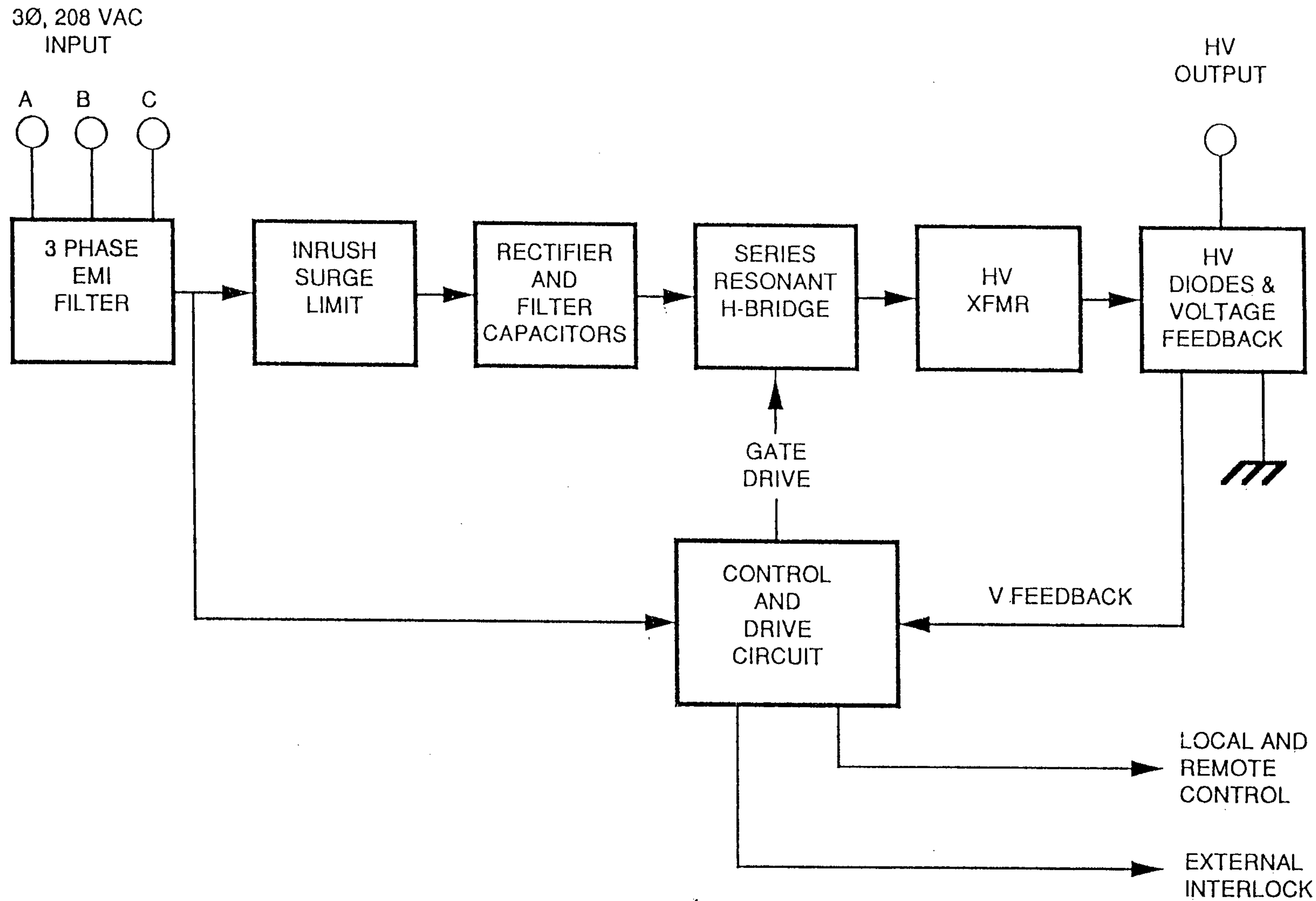


Figure 4-1. Power Supply Block Diagram

MLG-32.021

SECTION 5
SERVICE

WARNING

THE 208 VAC POWER IS PRESENT IN THE POWER SUPPLY WHEN THE CIRCUIT BREAKER IS CLOSED REGARDLESS OF THE STATUS OF THE FRONT PANEL CONTROL POWER ON/OFF SWITCH ON FULLY INSTRUMENTED MODELS. THIS VOLTAGE MAY BE LETHAL. BEFORE WORKING WITHIN THIS EQUIPMENT, TURN OFF THE MAIN 3Ø AC INPUT POWER AT THE CIRCUIT BREAKER, DISCONNECT THE AC POWER FROM THE SOURCE AND WAIT A MINIMUM OF FIVE (5) MINUTES FOR THE ENERGY STORED IN THE AC FILTER CAPACITORS TO DISSIPATE. UPON OPENING THE UNIT, DISCHARGE AND SECURELY GROUND THE FILTER CAPACITORS AT THE TERMINALS MARKED "INPUT" LOCATED IN THE CENTER OF THE INVERTER PCB.

CAUTION

THE MAKING OF ADJUSTMENTS TO A MODULE MUST BE DONE BY MAXWELL SINCE SEVERE DAMAGE MAY OCCUR DUE TO IMPROPER DAJUSTMENT. ANY WARRANTY SERVICE MUST BE PERFORMED BY OR UNDER THE DIRECT SUPERVISION OF FACTORY QUALIFIED PERSONNEL ONLY.

All servicing must be couducted or supervised by Maxwell service engineers. The power supply is modular and the modular sections can be removed for servicing or exchange under the direction of supervision of Maxwell service engineers. It is, therefore, recommended that the product be returned to Maxwell for servicing, for both warranty and after warranty repair. Prior to shipping a power supply for service, call the Maxwell Sales Office at 1-800-854-1505 to obtain a "Returned Goods" number.

SECTION 6
WARRANTY SUMMARY

This product is sold by Maxwell under the warranty set forth in Maxwell's Standard Terms and Conditions of Sale.

The warranty is only extended to the buyers purchasing the product directly from Maxwell or a Maxwell distributor.

SECTION 7
PARALLEL OPERATION

The power supplies can be operated in parallel to increase the output charging current. This is done utilizing a master/slave configuration in which the slave supplies are automatically controlled by the master supply which is interfaced to the user. The master/slave interconnections are done via the "Master/Slave Interconnect Cable Assembly" available from Maxwell. Any supply in the system can be an instrumented or non-instrumented version. When operated in the master/slave configuration, the following are applicable:

1. The HV ONOFF, voltage programming, and voltage and current monitor functions should all be accessed from the master unit. For instrumented master units, this can be done locally or remotely.

2. An interlock opening in the master supply will shut down the entire system, however, an interlock opening in a slave supply will result in the shutdown of that supply only. Therefore, it is recommended to use the "external interlock" function of the master unit only.

SECTION 8
HIGH VOLTAGE OUTPUT CONNECTION

The high voltage output is accessed on the rear panel with the high voltage coaxial cable assembly. For maximum personnel safety, Maxwell recommends that the shield on the HV output cable assembly be connected to the HV ground return stud located next to the HV output connector on the rear panel. Maxwell recommends the chassis of the power supply be securely grounded to the system ground in a low inductance manner.

SECTION 9
MOUNTING

The power supply is contained in a standard 19 inch wide X 8.75 inch tall rack mounted chassis. When mounting the supply in a rack mount cabinet, the power supply must be supported by chassis slides or support brackets in order to avoid excessive stress on the front panel. The power supply can be fitted with rolling chassis slides at the factory as an option.

Allow a minimum of three (3) inches of space at the rear of the supply for proper air flow and cooling.

CAUTION

The power supply is designed to operate in a horizontal position ONLY. Operating the supply in a vertical position can result in damage to the unit.

For applications requiring non-horizontal mounting, contact the Maxwell Sales Office at 1-800-854-1505 for consultation with an applications engineer.

SECTION 10
APPLICATION NOTES AND COMMENTS

10.1 Charging Large Capacitor Banks.

Since the output of the CCDS power supply is a constant current, the full power capability of the supply can be realized only when set for maximum rated output voltage. In applications where large parallel banks of capacitors with high leakage currents are charged then held for a period prior to discharge, the power supply may not be able to supply the leakage current and maintain the preset "keep alive" voltage once the capacitor bank is charged. The "keep alive" output current level can be internally adjusted to overcome this situation. Contact the Maxwell Sales Office at 1-800-854-1505 for consultation with an applications engineer.

10.2 Overvoltage/No Load Condition.

The CCDS power supplies are designed to latch in the HV OFF state if the output voltage exceeds 110 percent of the maximum rated voltage level. The Overvoltage Protection (OVP) circuitry will protect the power supply in the event of an accidental open circuit output connection or no load condition. The user should make every effort to prevent this condition from occurring. If the supply latches in the HV OFF state, the HV indicator(s) will indicate the HV OFF state and the voltage monitor will read a constant voltage. These symptoms indirectly tell the user an overvoltage condition has occurred. In instrumented units, the power supply control power must be cycled ON/OFF to return the supply to an operational mode. In non-instrumented units, the main 3ø power must be cycled ON/OFF to return the power supply to an operational mode.

10.3 Output Voltage Reversal.

CAUTION

Voltage reversal greater than 10 percent of the rated output voltage will cause damage to the power supply unless external protection circuitry is provided.

The CCDS-225 power supply is designed to operate with a maximum voltage reversal of 10 percent of the rated output voltage on a single-shot or fault basis. For applications in rep-rate power conditioning systems subject to repetitive voltage reversal, contact Maxwell application engineers at 1-800-854-1505 for a recommended power supply protection circuit.

If the system being driven by the power supply is under-damped during the discharge period and voltage reversal is anticipated, the factory should be consulted so a proper external protection circuit design can be provided which will protect the power supply from damage.

10.4 Special Applications.

For special applications not outlined in this manual, please consult Maxwell at 1-800-854-1505 for information and/or specific details regarding your needs.

SECTION 11
TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSE
Power supply does not turn ON when front panel switch is activated.	Rear panel breaker is not switched to ON position.
Front panel High Voltage ON Switch cannot be activated.	External rear panel interlock connection not made properly on TB201.
	High voltage output is open circuited and over-voltage circuit has latched. Connect proper load and recycle front panel ON/OFF switch.
	Power supply is wired for remote operation. Check J201 wiring on Pin 8.
High Voltage ON can be activated, but no output voltage is produced.	J201 Pin 7 is miswired.
	High voltage output is shorted at load.
High Voltage ON cannot be activated by remote control via J201.	Pin 8 is not grounded.
	High voltage output is open circuited. O.V.P. circuit has tripped.
	J201 remote interface is wired improperly.
	TB201 external interlock connection is not made.

For problems not covered in the Troubleshooting Guide, contact Maxwell Sales Office at 1-800-85[illegible]5.

Appendix A3
B-Pure Pressure Cartridge System
Series 583
Operation Manual/Parts List

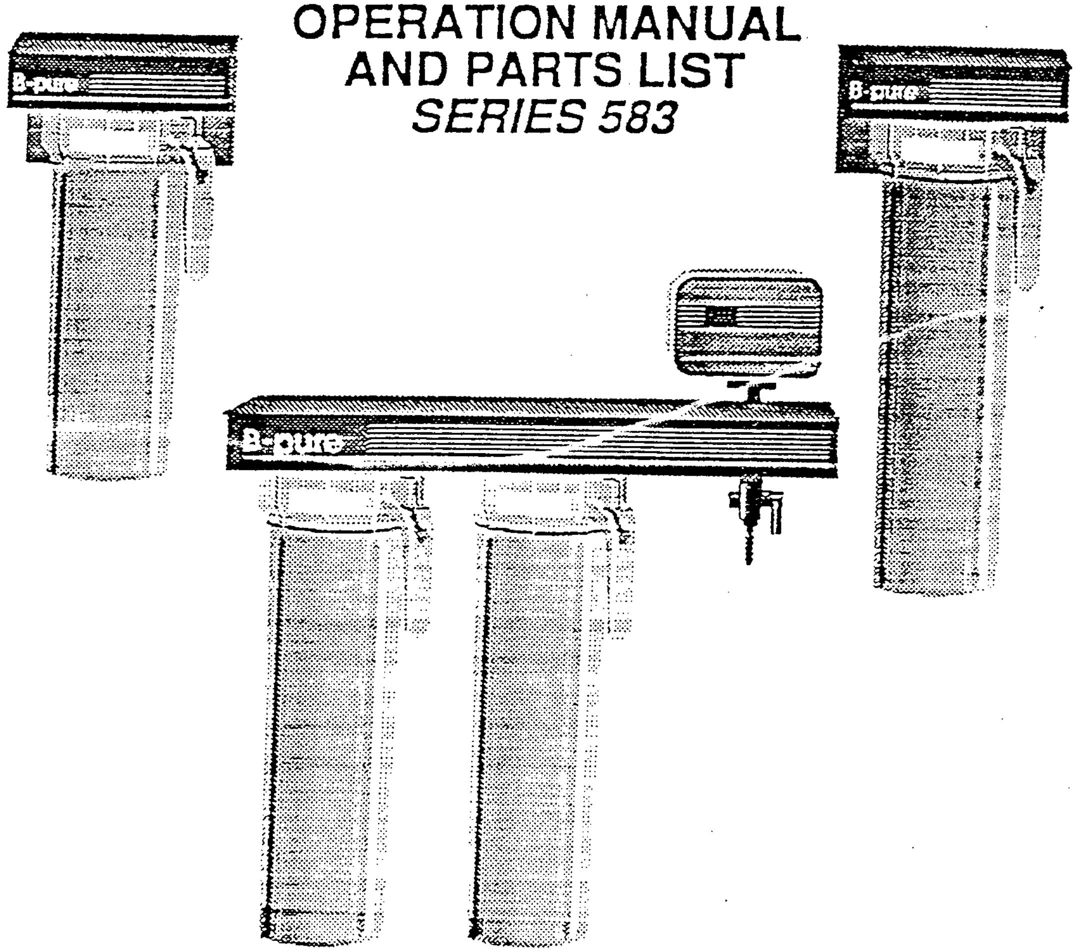
Barnstead

Barnstead|Thermolyne Corporation

B-Pure Pressure Cartridge System

OPERATION MANUAL AND PARTS LIST

SERIES 583



Model #	Voltage	Model #	Voltage
D4505		D4525	240
D4511		D5831	120
D4521	120	D5832	240
D4522	240	D5833	120
D4523	100	D5834	240
D4524	120	D5839	

LT583X1 • 3/13/91

Serial Number: ______________________

IMPORTANT INFORMATION
This manual contains important operating and safety information. The user must carefully read and understand the contents of this manual prior to the use of this equipment.

Table of Contents

Safety Information

Your Barnstead B-Pure Pressure Cartridge System has been designed with function, reliability, and safety in mind. It is the user's responsibility to install it in conformance with local electrical codes. For safe operation, please pay attention to the alert boxes throughout the manual.

Alert Boxes

WARNING
Warning alerts apply when there is a possibility of personal injury.

CAUTION
Caution alerts apply when there is a possibility of damage to the equipment.

NOTE
Notes alert the manual user to pertinent facts and conditions.

Warnings

WARNING

To avoid electrical shock, always:

1. Use a properly grounded electrical outlet of correct voltage and current handling capacity.
2. Avoid mounting B-pure directly over equipment that requires electrical service. Routine maintenance of this unit may involve water spillage and subsequent electrical shock hazard if improperly located.
3. Disconnect from the power supply prior to maintenance and servicing.

To avoid personal injury:

1. Avoid splashing disinfecting solutions on clothing or skin.
2. Ensure all piping connections are tight to avoid leakage of chemicals.
3. Always depressurize chemical lines before disassembly.
4. Carefully follow the manufacturer's safety instructions on labels of chemical containers.
5. Refer servicing to qualified personnel.

Installation

Installation Notes

The cartridge holders that make up the B-pure family are designed for a wide range of applications and configurations. It is not possible to include specifics in this manual for the broad application range. Barnstead recommends that you contact your local representative or Barnstead/Thermolyne Customer Service for guidance. Knowing the correct cartridges or filters for your specific application will assure you of the most efficient and economical use of your B-pure System.

All individual members of the B-pure family can be interconnected to form custom water treatment systems. If you are constructing a custom system, be sure to read the *Mix & Match* section *before* mounting the system. The mounting hole patterns will vary depending on the particular configuration that you choose.

The B-pure system requires expendable pretreatment, prefilters, deionization cartridges and final filters which are not supplied with the unit. They must be purchased separately. Descriptions, applications and catalog numbers of filters and cartridges are on pages 12 and 13. When ordering, please state catalog number, description and quantity required. *Screws and fasteners required for wall mounting are not supplied with the unit.*

Technical Specifications

Feedwater Requirements

Types	Tap, RO, DI, distilled
Maximum pressure	7 kg/cm^2 (100 psig) maximum
Temperature	4–49°C (40-120°F)

Installation

Mounting	Wall mount, with bracket provided		
Dimensions, mm (in.)	*Dual B-pure*	*Single B-pure*	*Half-size Holder*
Width	381 (15)	178 (7)	178 (7)
Depth	171.5 (6 3/4)	171.5 (6 3/4)	171.5 (6 3/4)
Height	673 (26 1/2)	591 (23 1/4)	368 (14 1/2)
Op. weight, kg (lbs)	12.7 (28)	5.9 (13)	5 (11)
Plumbing Connections			
Inlet	1/2" NPTF	1/2" NPTF	1/2" NPTF
Outlet	1/2" NPTF 1/4" NPTF 5/16" OD Hose barb	1/2" NPTF	1/2" NPTF

Resistivity Measurement

Range	0.1–18.3 megohm-cm (Temperature Compensated to 25°C/77°F)
Accuracy	±1.0 megohm-cm
Cell	0.1 constant
Electrical Requirements	
120 VAC, 50/60 Hz	108-132 VAC, 47-63 Hz, 5 Watts
240 VAC, 50/60 Hz	216-264 VAC, 47-63 Hz, 5 Watts

Installation

Unpacking

Unpack the B-pure carefully. B-pure units come completely assembled. A spare head interconnector (15853) is supplied as a loose part with the single B-pure (D4511) and the 1/2 B-Pure (D4505 and D5839). Retain this item for possible later use in expansion.

System Location

The B-pure should be mounted at a convenient height for routine operation. Adequate front access will be required for cartridge or filter exchange and reading of the resistivity meter, if used. The following clearances are necessary:

- Left and right side clearance
  - All B-pure products, 4" minimum
- Free space below canisters
  - All B-pure products, 4" minimum
- Free Space Above *Center* of Wall Bracket
  - All B-pure products *without* meter, 4" minimum
  - B-pure products *with* meter, 8" minimum

WARNING

Do not mount B-Pure directly over equipment that requires electrical service. Routine maintenance of this unit may involve water spillage and subsequent electrical shock hazard if improperly located.

The recommended dimensions for mounting hardware to support your equipment are:

- Body Diameter, 1/4" maximum
- Head Diameter, 3/8" maximum
- Length, 1" typical

CAUTION

Wall and mounting hardware must be capable of supporting the full operational weights as outlined in the technical characteristics section of this manual. Inadequate support or fasteners may result in damage to mounting surface and/or equipment. Use adequate hardware for the job. If you are unsure of the hardware, consult your building maintenance group or contractor..

Mounting and Utility Connections

All B-pure installations require a user supplied shutoff valve in the incoming water service line. In some installations, it may be desirable to provide an outlet shutoff valve. A drawoff valve assembly is provided on the Dual Holders as a standard and may be ordered as an optional extra for other B-pure products. (See exploded view drawing for part numbers.)

NOTE

If you are constructing a custom water treatment system using B-Pure components, read the *Mix and Match* section of this manual before proceeding further.

Mount the B-Pure unit using the following steps:

1. Remove the wall brackets from the unit by removing the two securing screws on the left and the right bottom portion of the brackets. Slide brackets downward to release.
2. Using the wall brackets as a template, mark the hole locations on the wall.
3. Drill holes in wall suitable for the selected fasteners .
4. Mount wall brackets and secure with fasteners.
5. Re-secure B-Pure on brackets and refasten securing screws.
6. Connect feedwater service to the left side of the head assembly using adapter provided. Use Teflon® tape on threads to assure a leak-free connection.

CAUTION

Do not overtighten this connection — excessive tightening will crack the adapter.

7. Make outlet connections as required by your specific application.

® *Registered trademark of DuPont*

Initial Operation

Initial Operation

Various types of filters and cartridges are used in B-pure systems; 10" nominal particulate filters and cartridges are used in the half-size canisters and nominal 17" water treatment cartridges used in the full size canisters.

Installing Water Treatment Cartridges

1. Remove the cartridge from the bag..
2. Remove the canister from the head by depressing the thumb lever and rotating the hand ring 1/4 turn to the left.
3. Check to ensure that the small o-ring inside the head is in place. This is important because water will bypass the cartridge if this o-ring is not in place.
4. Place cartridge(s) in canister with the large opening down.
5. Wet canister o-ring before installation. Install canister by depressing thumb lever and rotating 1/4 turn to the right, until the locking pin is in appropriate position (see figure 1).

CAUTION
Secure locking pin before operating. Locking pin on canister must be fully released into hole in head before system is operated.

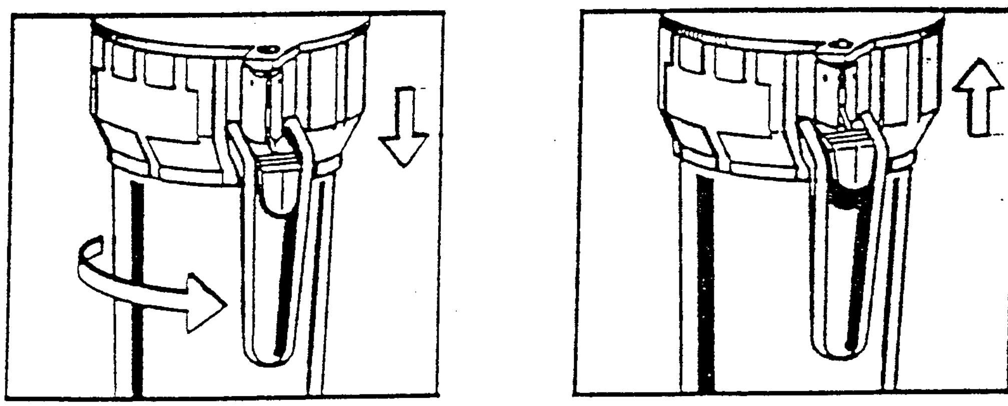


Figure 1: Canister locking pin position

NOTE
An extra set of head-to-canister O-rings are supplied. These can be used to replace any O-rings that may have been damaged or deformed in shipment.

Installing Particulate Filters

Two types of particulate filters are used in the half-size canisters.

Prefilters These devices are string-wound filters designed to prevent large particulates from entering a water treatment system.

Final Filters These devices are pleated membrane filters designed to remove particulates as small as 0.2 micron. These filters are supplied with gaskets which are not used for B-Pure installations.

Install filters as follows:

1. Remove filter and adapters from package.
2. Remove canister from head by pressing the thumb lever and rotating the ring 1/4 turn to the left.
3. Lubricate the o-rings on the adapters using pure water, then install adapters into filters by turning the adapter as you push it into the filter's open end.
4. Lubricate the o-rings on the head, then secure the filter (including adapter) onto the head by gently pushing and turning the filter.
5. Insert the canister vertically upward over the filter and tighten 1/4 turn to the right.

CAUTION
Secure locking pin before operating — locking pin must be fully released into hole on head before the system is operated.

Filling Procedure

After every cartridge exchange, some air will be trapped in the system. Air should be purged before routine use by the following procedure:

1. Place a container or suitable drain under the outlet valve.
2. Open all inlet valves and the outlet valve.
3. When there is a steady flow from the outlet valve, close the outlet valve.

NOTE
When using a submicron filter, hold purge button (red button on holder head) down until a steady flow of water is observed. Check all fittings for leaks and tighten as necessary.

4. If using a resistivity meter, plug into electrical service.
5. Open the outlet valve and allow water to flow through the system until desired purity is reached.

Operation

Prior to withdrawing water for use, it is recommended that the user allow some water to run to drain to rinse up the system. If using a resistivity meter, the display will register a gradual improvement of water quality.

Resistivity Meter/Pura-Lite

The resistivity measurement in the dual holder B-pure is accomplished with an in-line digital readout meter and integral cell. The resistivity meter measures the specific resistance of the water on a scale of 0.1 to 18.3 megohm-cm. The resistivity measurement is automatically temperature compensated to 25°C regardless of system water temperature.

Other systems may include a Pura-Lite. These lights are go/no-go indicators. The light will illuminate green when the purity of the water exiting the system is above the value of the individual light. When the purity drops below that value, it will illuminate red, indicating the need for cartridge replacement.

Maintenance and Servicing

WARNING

To avoid electrical shock, always disconnect from power supply before maintenance and servicing. Refer servicing to qualified personnel.

Cartridge and Filter Replacement

Depending on your particular usage, cartridges must be periodically replaced. The need for replacement of water treatment cartridges designed to remove ionized impurities can be determined by a drop in resistivity of the water. For 10" particulate filters, replacement can be determined by a significant drop in pressure or a decrease in flow rate. Change all cartridges as follows:

1. Close the customer-supplied shutoff valve on the inlet side of the system.
2. Place a suitable container under the outlet and open the outlet valve to depressurize the system.
3. Place a container under the cartridge canister to collect any spillage.
4. Release the canister from the head and drain into container.
5. Remove old cartridge and discard.
6. Inspect the o-rings in the canister and replace if worn.
7. Install a new cartridge or filter as explained in Initial Operation.

System Sanitization

Frequency of cleaning is difficult to determine because of the wide variety of feedwater supplies, however the need for cleaning can be easily determined. Whenever a cartridge is replaced, always examine the inside of the canister for any residual deposits. If any are observed, clean the system as follows:

1. Disconnect power to system where appropriate.
2. Close the shutoff valve on the inlet side of the system.
3. Relieve pressure by opening and closing the outlet valve.
4. With the cartridges out of the canisters, wash the inside of the heads and canisters with soap or detergent, using a sponge or clean cloth. Rinse out the canisters and heads with clean water several times to remove the detergent residues.

NOTE

The following sanitizing solution is sufficient for one large canister. Prepare a sufficient amount of solution to fill all of the canisters in your system.

5. Make up the following disinfecting solution: add 230 milliliters of bleach (5.25% sodium hypochlorite) to 3.8 liters of water to make a 0.3% solution.
6. Fill each canister to within 2" of the top with the above disinfecting solution, and reassemble the canisters on the unit.
7. Open the shutoff valve on the inlet side of the system.
8. Open the outlet valve and draw off approximately 200 ml. of solution. Discard this solution
9. Close inlet and outlet valves.
10. Allow the disinfecting solution to stand for one half hour.

11. Open the inlet and outlet valves and flush the system for 10 minutes.
12. Close the shutoff valve on the inlet side of the system and open the outlet valve to depressurize the system.
13. Carefully remove all the canisters from the system, and discard the solution remaining from the canisters. Do not rinse the canisters.
14. Install fresh cartridges in the system as explained in *Initial Operation.*
15. Turn to the Operation section of this manual for filling procedure and normal operation.

Cleaning the Resistivity Cell

Clean the resistivity cell as follows:

1. Disconnect power to the system.
2. Close the shutoff valve on the inlet side of the system.
3. Open the outlet valve.
4. Remove meter and cell assembly from the head.

CAUTION
The cell electrodes are etched to improve wetting characteristics. Do not mechanically abrade or damage this surface.

5. Wash the cell in a mild detergent solution or a 10% inorganic acid solution (follow manufacturer's recommended handling procedure). This may be done in an ultrasonic cleaner or with a soft brush. The cell must be thoroughly rinsed in deionized water following the detergent or acid cleaning.

CAUTION
Do not immerse the entire cell assembly in the cleaning solution, only the electrode portion.

After cleaning, remove old Teflon tape from the head and cell threads and apply a fresh wrap of Teflon tape to cell body threads. Install the meter assembly in the B-Pure System.

CAUTION
Do not overtighten cell. Excessive tightening will crack the head.

Storage

If the B-pure System is to be shut down for an extended period of time, the system should be completely drained and the cartridges removed to prevent the growth of bacteria.

If the system has remained inactive and full of water, then the system should be drained, cleaned, and sanitized before new cartridges are installed.

Troubleshooting Guide

Problem	Possible Causes	Solutions
Water will not rinse up to purity	• Exhausted cartridges	• Replace all cartridges as explained in the *Maintenance and Servicing* section
	• Cartridges upside down	• Install the cartridges right-side-up as explained in the *Initial Operation* section
	• Cartridges out of order	• Verify that cartridge order is correct for your specific application
	• Feedwater bypassing cartridge(s)	• Be sure o-ring is not damaged and is properly installed
	• Excessive flow rate	• Reduce flow to specified maximum or less
Reduced or no water flow	• Particulate filter clogged	• Replace the filter as explained in the *Maintenance and Servicing* section
	• Air trapped in filter	• Purge air in the system as explained in the "Purging Air From the System"
Leaking canisters	• O-ring missing, damaged or not seated properly in the groove of the canister	• Replace or position correctly
Short cartridge life	• Cartridges being used are beyond expiration date	• Check the expiration date — cartridges begin to lose capacity after being stored two years from date of manufacture; replace the cartridges with fresh ones
	• Change in feedwater characteristics	• If tap water is the feedwater source, check the quality of the water — in some cases, the quality of the water will change with the seasons; changing the source (city water to well water or vice versa) will result in a water quality change (if feedwater if from a central water purification source, [illegible] water quality and pr[illegible] functioning of the system
Excessive particulate passage	• One or both filter adapters missing or installed improperly	• Check that the adapters are installed on the filters properly, and that their o-rings are in place

Mix and Match

Introduction

All B-pure products are designed for interconnection to form a variety of water systems. Individual applications will determine the correct sequence of B-pure components. After the sequence is determined the various parts can be easily arranged and connected. In this section we describe the general procedure for constructing a custom system and detail the procedures for constructing two commonly used configurations. We recommend you read the entire section before proceeding.

Tools and Accessories

Constructing a custom system will require the following tools:

- Small screwdriver for drive pin removal.
- A small mallet or hammer for re-seating the drive pins.

General Procedure

After carefully unpacking B-pure components place them on a table in the desired order. As a general rule, if you are using a dual holder B-pure it should be located as far to the right as possible. This will reduce the number of changes that need to be made.

> **CAUTION**
> Do not attempt to get the correct sequence by interchanging just the cartridge canisters. The half filter holder (D5839) requires a special head. Always use the half-size canister with the head that has the red vent button and lever.

Next remove all of the fastener pins in the canister heads where two heads touch each other and remove the adapters or assemblies retained by the fastener pins. Fastener pins are removed by gently tapping them up with a screwdriver. Set the fastener pins and other parts aside. If you have a dual holder B-pure, it is not necessary to remove the factory installed fastener pins that join the heads.

Locate the head interconnectors (BR550X4) supplied as loose parts and install these wherever heads need to be joined. Make sure that the o-rings are still in the recesses of the heads. Re-install fastener pins and tap gently with a hammer until they are seated.

You should now have a rigid assembly of heads and wall brackets in your desired sequence. Inlet and outlet adapters or assemblies can now be installed to suit your particular requirements. Turn to the *Mounting and Utility Connections* section of this manual for mounting instructions.

Three Holder B-pure Unit *(Two DI Cartridges and one Filter Cartridge)*

A common configuration built from B-pure component is the three holder unit. This unit allows the use of two water treatment cartridges and a final filter at the outlet. This will require one dual B-pure and a 1/2 B-Pure (D5839).

Disassemble the units as follows:

1. Position the dual holder on the left and the half filter holder to its right.
2. Remove all the canisters.
3. Remove drawoff valve assembly from the dual holder by driving up the fastener pins.
4. Remove the end fitting on the inlet and outlet of the Half Filter Holder.

Reassemble the units as follows:

1. Install the head interconnector into the outlet port of the dual holder. Be sure o-ring is in place. Install and seat fastener pins.

2. Connect the Half Holder head into the dual holder head so that the interconnector from the Dual Holder is in the inlet port of the Half Holder. Be sure o-ring is in place. Install and seat fastener pins.
3. Install drawoff valve assembly, including meter, into the half holder outlet port. Be sure the o-ring is in place. Install and seat fastener pins.

Turn to the *Mounting and Utility Connections* section of this manual for mounting instructions.

Three Holder B-pure (Three Water Treatment Cartridges)

A common configuration built from B-pure components is a Three-Holder System. This system will utilize three water treatment cartridges in series. This will require a Dual Holder and a single holder B-pure (D4511).

> **NOTE**
> Figure 2, page 14, can be used as a guide for assembly order.

Disassemble the unit as follows:

1. Position Dual Holder on right and single holder on left on top of table.
2. Remove the canisters from all units.
3. Drive up fastener pins from the outlet of the single holder and the inlet of the dual holder and remove end fittings.

> **NOTE**
> This is accomplished by gently tapping from the bottom with a small screwdriver and a hammer — excessive force will damage the pins.

4. Connect the two units together using the head interconnector supplied. Ensure that the o-ring is present in both openings. Install and seat fastener pins.
5. Turn to the *Mounting and Utility Connections* Section of this manual for mounting instructions.

Cartridges and Filters

Description	Half size Catalog no.	Full size Catalog no.	Application
Macropure	N.A.	D0836	Effectively removes colloids, bacteria, chlorine and organics, increases filter life.
Pretreatment	N.A.	D0835	Effectively removes colloids, bacteria organics and chlorine.
Still Pretreatment	D50217	D0832	Removes ionized impurities and has a layer of activated carbon to remove chlorine and organics.
Organic Removal	D50215	D0813	Removes organics and chlorine.
Cation	N.A.	D0815	Converts ionized salts to the acid form resulting in a product water that is low in pH, ideal for precious metal or isotope recovery.
Anion	N.A.	D0760	Effective removal of weakly ionized impurities, raises the pH of solutions, recovers precious metal complexes.
High Capacity	N.A.	D0803	Removes ionized impurities, produces a larger quantity of water than that of the Ultrapure, however at a lower resistivity.
Ultrapure	D50213	D0809	Removes ionized impurities to produce high resistivity water with a neutral pH.
Oxygen Removal	D50214	D0811	Maintains low oxygen content to prevent corrosion in cooling water loops, etc. The feedwater should contain less than 10 ppm of ionized solids.

Prefilters

Description	Half size catalog no.
15 micron	FL583X3
10 micron	FL583X2
5 micron	FL583X1

Final Filters

0.45 micron	FL583X5
0.2 micron	FL583X6

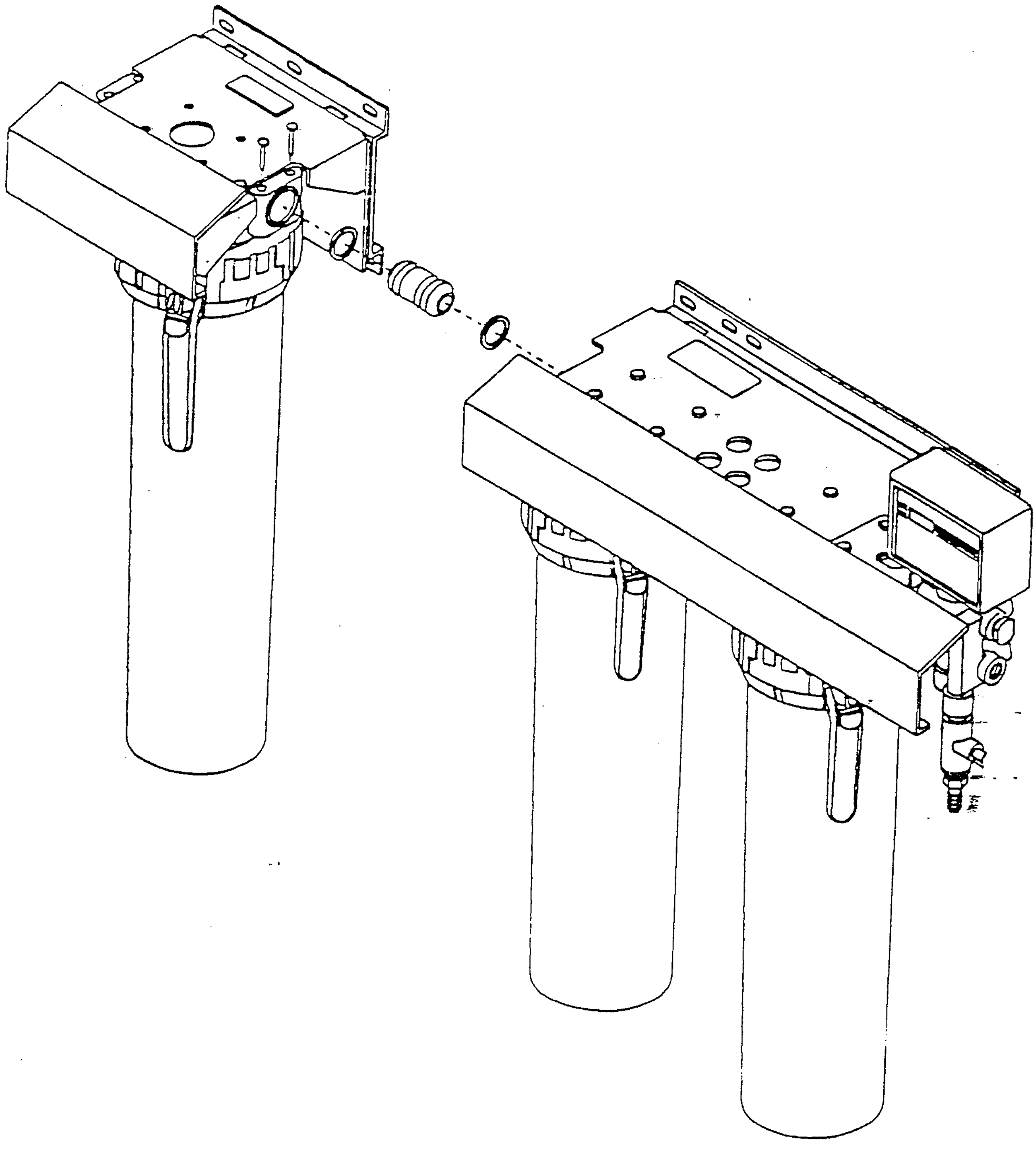
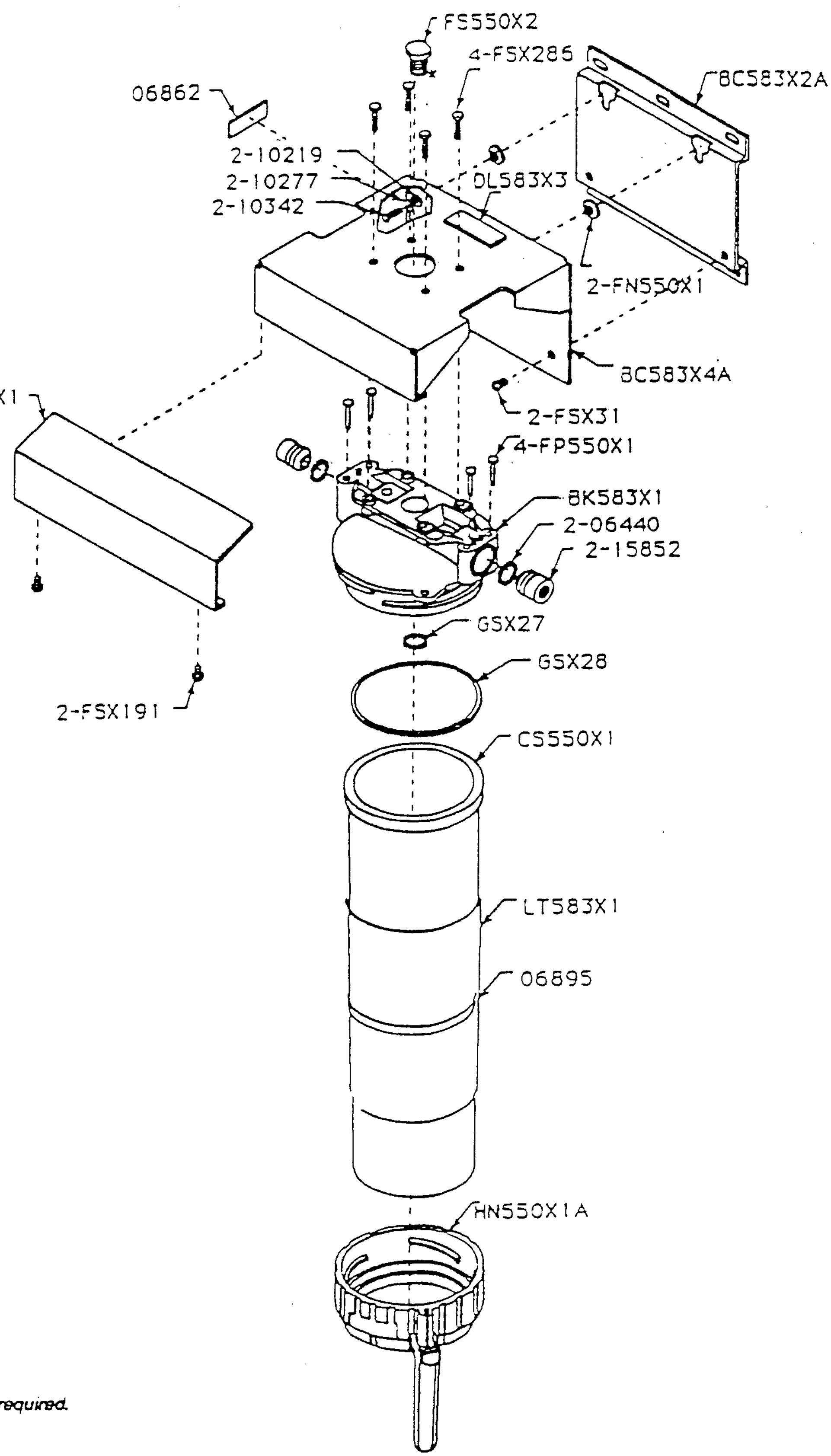
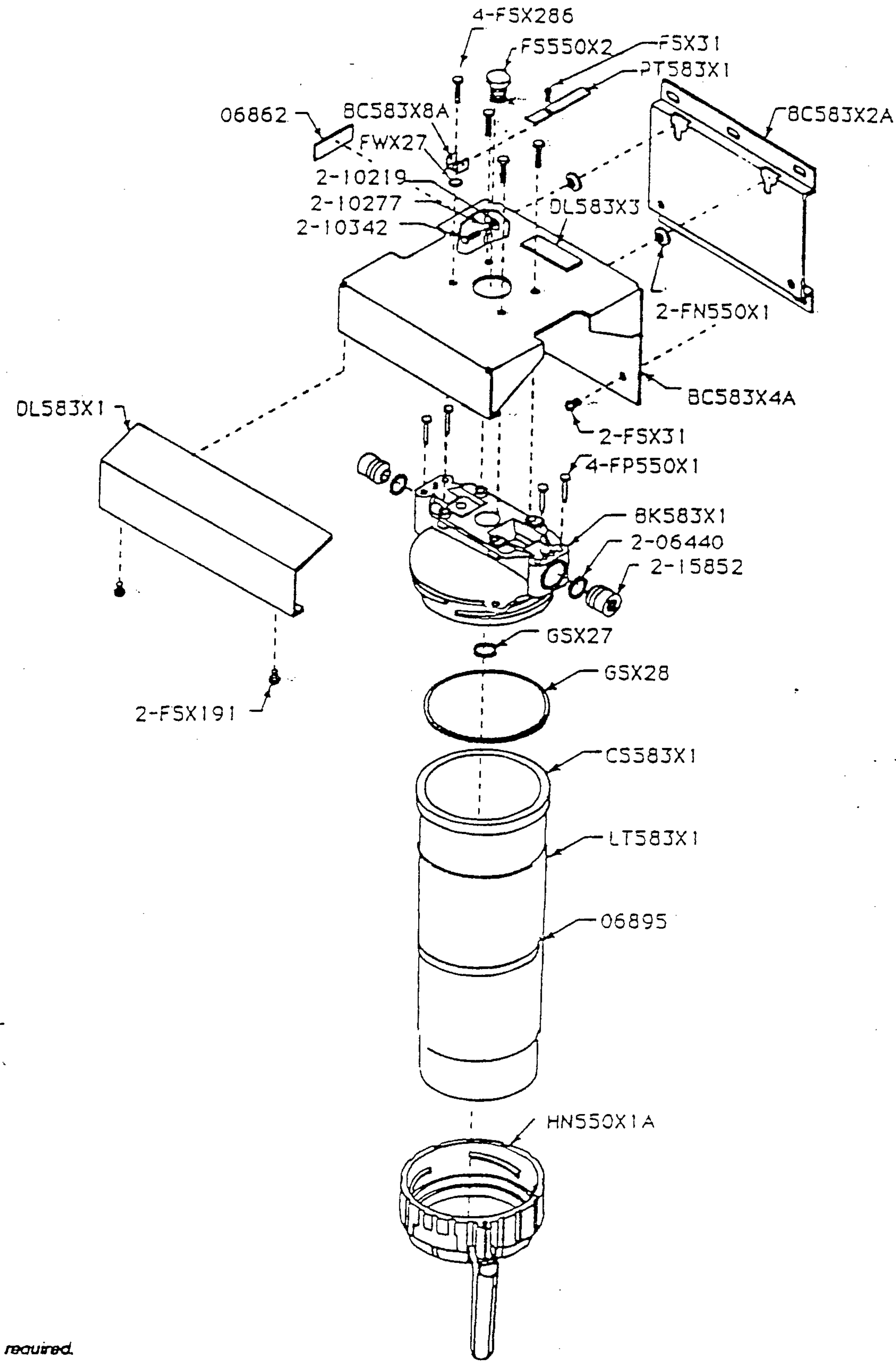


Figure 2: Three-holder B-pure (Three Water Treatment Cartridges)



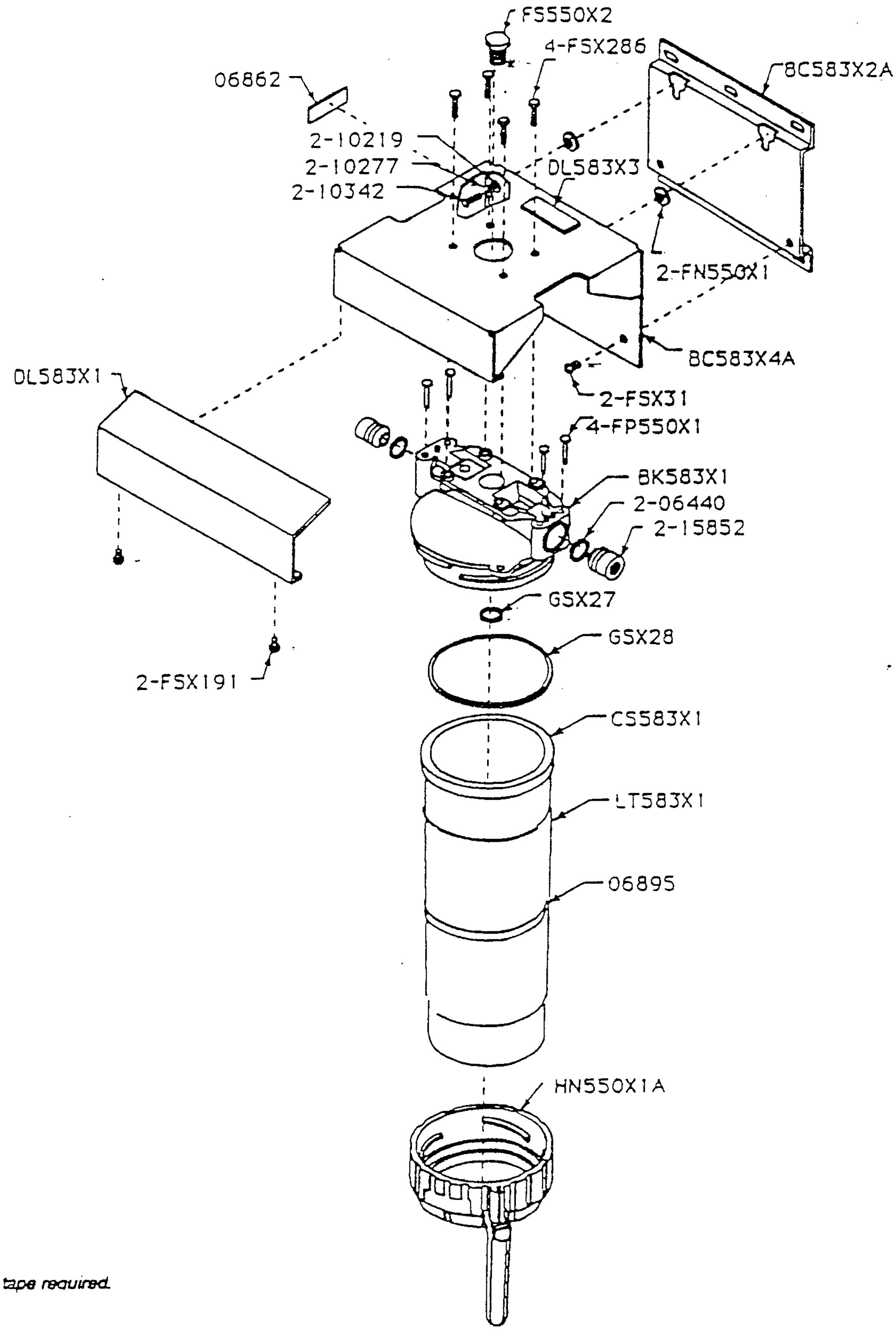
*Teflon® tape required.

Figure 3: Exploded view B-pure (D4511)



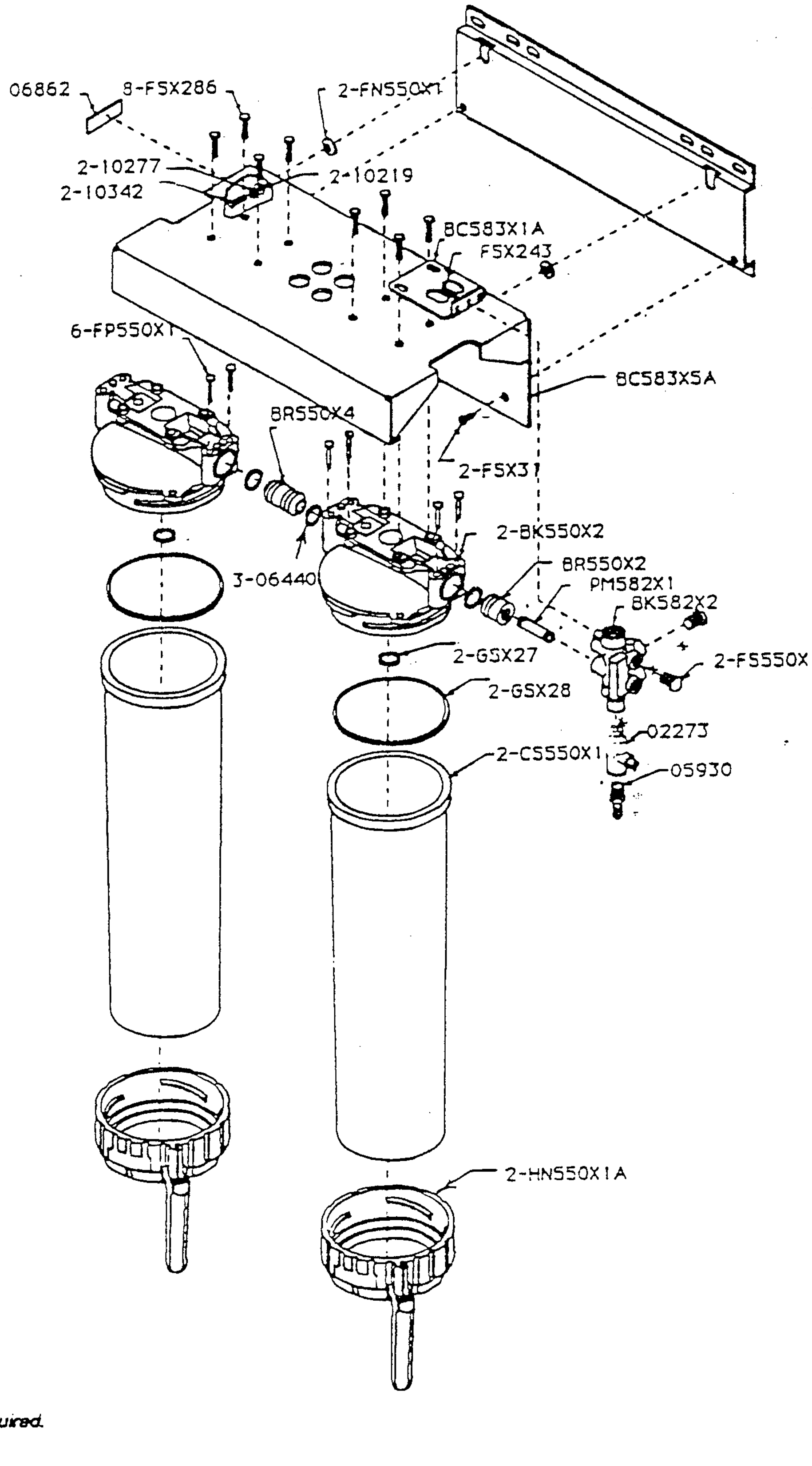
*Teflon® tape required.

Figure 4: Exploded view B-pure (D4505)



*Teflon® tape required.

Figure 5: Exploded view B-pure (D5839)



*Teflon® tape required.

Figure 6: Exploded view for Dual Holder B-pure

Replacement Parts Listing

WARNING

To avoid electrical shock, always disconnect from power supply before maintenance and servicing. Refer servicing to qualified personnel.

Recommended Spares

Consumable parts are those required to support the day-to-day operation of this equipment. Barnstead|Thermolyne establishes two types of consumables:

- Those items that must periodically be replaced to maintain performance (filters, resin cartridges, etc.)
- Other items of limited life (indicator lights, fuses, etc.) that the user can expect to replace on a more or less random basis.

The replacement of consumable parts is discussed in the *Maintenance and Servicing* section of this manual to assist the user in accomplishing his own service.

Consumables List

The only consumables used in the B-Pure products are user selected. The following chart is provided for the user as a means of recording the cartridges, part numbers (catalog numbers), and their location in the system.

Location (left to right)	Part # (Qty)	Description
1		
2		
3		
4		
5		
6		

General Maintenance Parts

General maintenance parts are defined as laboratory level repair parts which do not require great expertise or special tools for installation. Barnstead|Thermolyne recommends that the user stock the general maintenance parts as an aid to ensuring the continued operation of this equipment.

		Recommended Quantity		
Part #	**Description**	**1/2 B-Pure**	**Single B-Pure**	**Dual B-Pure**
GSX27	O-ring, cartridge head seal	1	1	2
GSX28	O-ring, large head seal	1	1	2
06440	O-ring (between heads)	1	1	4
FP550X1	Fastener pin	4	4	8
BR550X4	Head interconnector	N.R.	N.R.	1
15852	Connector (inlet/outlet)	1	1	1

Safety Stock

For critical applications where performance with minimum downtime is required, Barnstead recommends that the user maintain a local stock of those parts listed under "General Maintenance" and "Safety Stock." In the event of component failure, the safety stock can be drawn upon by the user or Barnstead technicians, thereby, avoiding unnecessary delays in delivery of replacement parts.

		Recommended Quantity		
Part #	**Description**	**1/2 B-Pure**	**Single B-Pure**	**Dual B-Pure**
BK550X2	Cartridge canister head	N.R.	1	2
BK583X2	Filter canister head	1	N.R.	N.R.
CS550X1	Full-size cartridge canister	N.R.	1	1
CS583X1	1/2-size filter canister	1	N.R.	N.R.
D2770	Resistivity meter, 115 VAC	N.R.	N.R.	1
D2769	Resistivity meter, 230 VAC	N.R.	N.R.	1
HN550X1A	Cartridge canister handle	1	1	1

Ordering Procedures

Please refer to the Specification Plate for the complete model number, serial number, and series number when requesting service, replacement parts or in any correspondence concerning this unit.

All parts listed herein may be ordered from the Barnstead|Thermolyne dealer from whom you purchased this unit or can be obtained promptly from the factory. When service or replacement parts are needed we ask that you check first with your dealer. If the dealer cannot handle your request, then contact our Customer Service Department at 319-556-2241 or 800-553-0039.

Prior to returning any materials to Barnstead|Thermolyne Corp., please contact our Customer Service Department for a "Return Goods Authorization" number (RGA). Material returned without a RGA number will be refused. Minimum invoice: $25.

One Year Limited Warranty

Barnstead|Thermolyne Corporation warrants this product to be free from defects in material and workmanship for a period of one year from date of purchase.

This warranty applies only to defects in original parts or components, and does not apply to claims or alleged product failures resulting from unauthorized repairs, misuse, accidents or lack of proper maintenance, failure to follow **Barnstead|Thermolyne's** instructions for use or from ordinary wear and tear.

Warranty service may be obtained by returning any defective product to an authorized **Barnstead|Thermolyne** dealer or to **Barnstead|Thermolyne.** Heating elements, because of their susceptibility to overheating and contamination, must be returned to our factory and if, upon inspection, it is concluded that failure is not due to excessive high temperature or contamination, warranty replacement will be provided.

BARNSTEAD|THERMOLYNE'S SOLE OBLIGATION UNDER THIS WARRANTY SHALL BE TO REPAIR OR REPLACE ANY PRODUCTS WHICH IT DELIVERS AND ARE FOUND TO BE DEFECTIVE.

THERE ARE NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, MADE IN CONNECTION WITH THE SALE OF THIS PRODUCT. BARNSTEAD|THERMOLYNE EXPRESSLY DISCLAIMS ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR SPECIFIC USE.

Barnstead

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Appendix A4
Cold Jet Model 65-200
Operators Manual

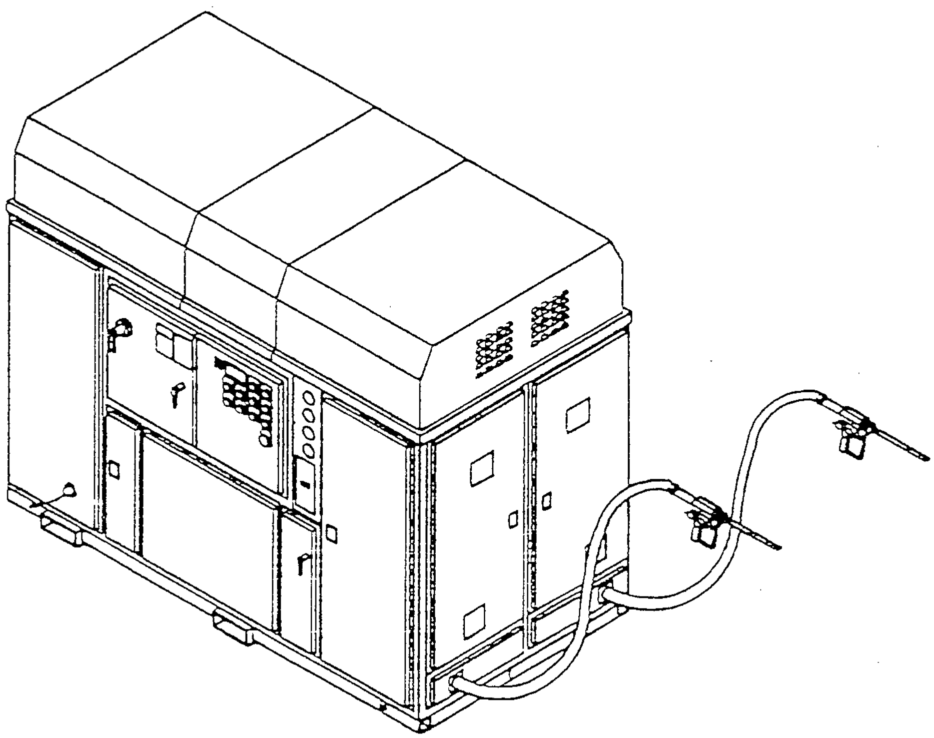
This manual is customer furnished data. The WR-ALC installation utilized a Cold Jet Model 65-200 government furnished unit. Use the manual supplied with the government furnished equipment for data refered to as Appendix A4.

COLD JET

The Force of Nature

OPERATORS MANUAL

COLD JET MODEL 65-200



The design contained in this manual was originated by, and is the exclusive property of Cold Jet, Inc. It is not to be used in any way detrimental to the interest of Cold Jet, Inc.

Technology / Characteristics	Xenon Flashlamp/ CO2 Pellet Blasting	CO2 Pellet Blasting	Xenon Flashlamp	LASER	Water Ice Blasting	Sodium Bicarbonate Blasting	Non-Phenol Based Chemical Softener/ Waterjet	High Pressure Water Jet (32,000 psi)	Wheat Starch Blasting	Phenol Based Chemical/ Water Rinse	Plastic Media Blasting (PMB)
Hazardous Waste Volume	Low (No Media)	Low (No Media)	Low (No Media)	Low (No Media)	Low	Low	Moderate	Low	Low	High	Moderate
Media Disposal Cost	None	None	None	None	None	Low	Low	None	Low	Very High	High
Media Recycle Requirement	None	None	None	None	Yes	Yes	None	Yes	Yes	None	Yes
Aircraft Precleaning Required	None	None	None	None	None	None	Yes	None	Yes	Yes	Yes
Adjacent Component Damage Potential	None	None	None	Low	Low	Yes	Low	High	Yes	Yes	Yes
Corrosion Potential	None	None	None	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Media Intrusion Potential	None	None	None	None	High	High	High	High	High	High	High
Post Stripping Cleanup Required	None	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AircraftThru-Put Rate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate	Low	Moderate
Paint Stripping Rate	High	Moderate	Low to Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Aircraft Damage Potential	Low	Moderate	Minimal	Low	Low	Low	Moderate	Moderate	Low	High	Moderate
Aircraft Masking Requirement	Minimal	Minimal	Minimal	Minimal	Extensive	Extensive	Extensive	Extensive	Extensive	Extensive	Extensive
Operator Safety Requirements	Ear/Eye	Ear/Eye	Ear/Eye	Lethal Energy	Eye	Breathing Ear Eye	Chem Burn	Lethal Blast	Breathing Ear Eye	Chem Burn	Breathing Ear Eye

Characteristics Rating

Best	Moderate	Worst

Figure 1. Investigation of Paint Strip Processes

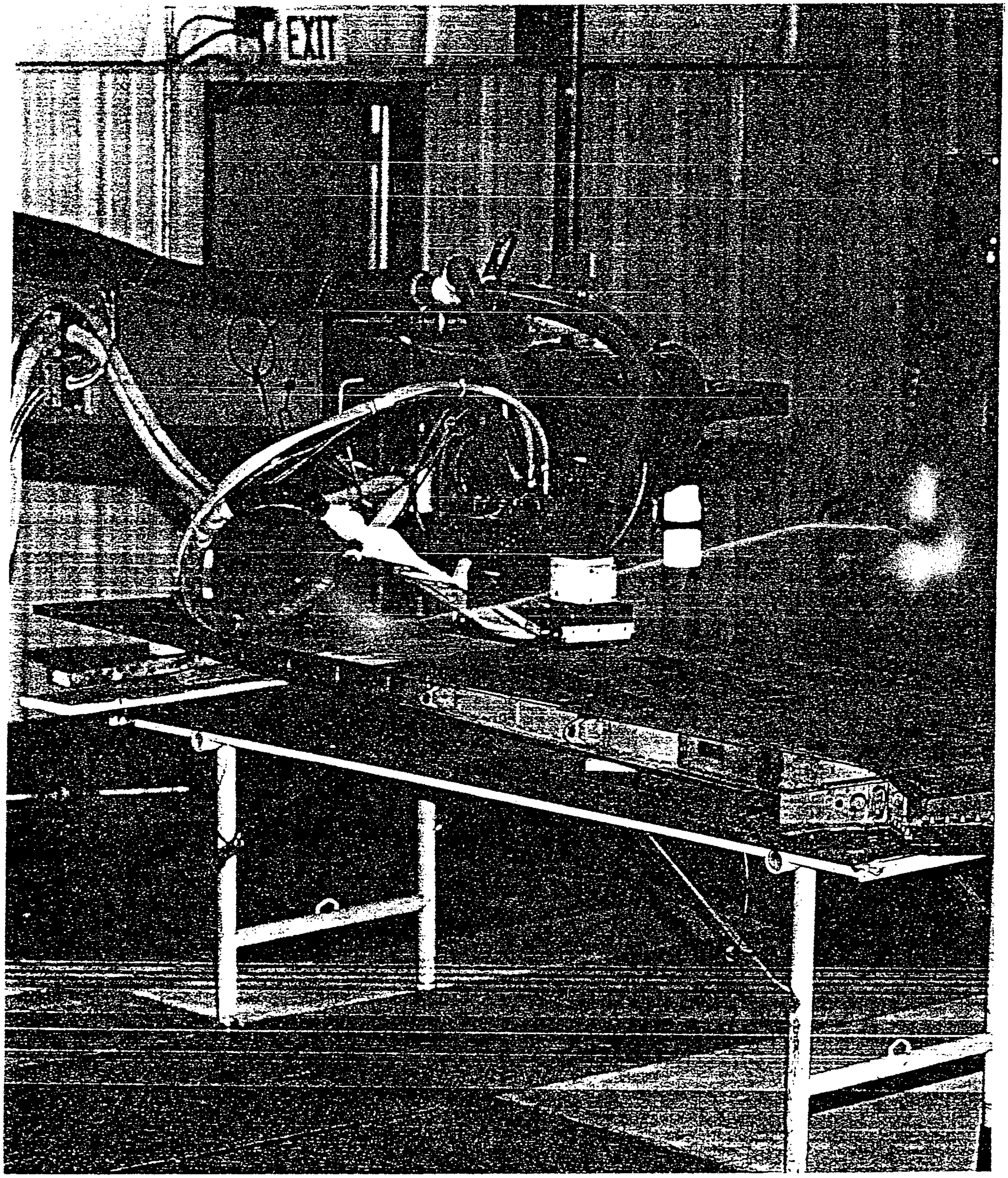


Figure 2. WR-ALC Installation

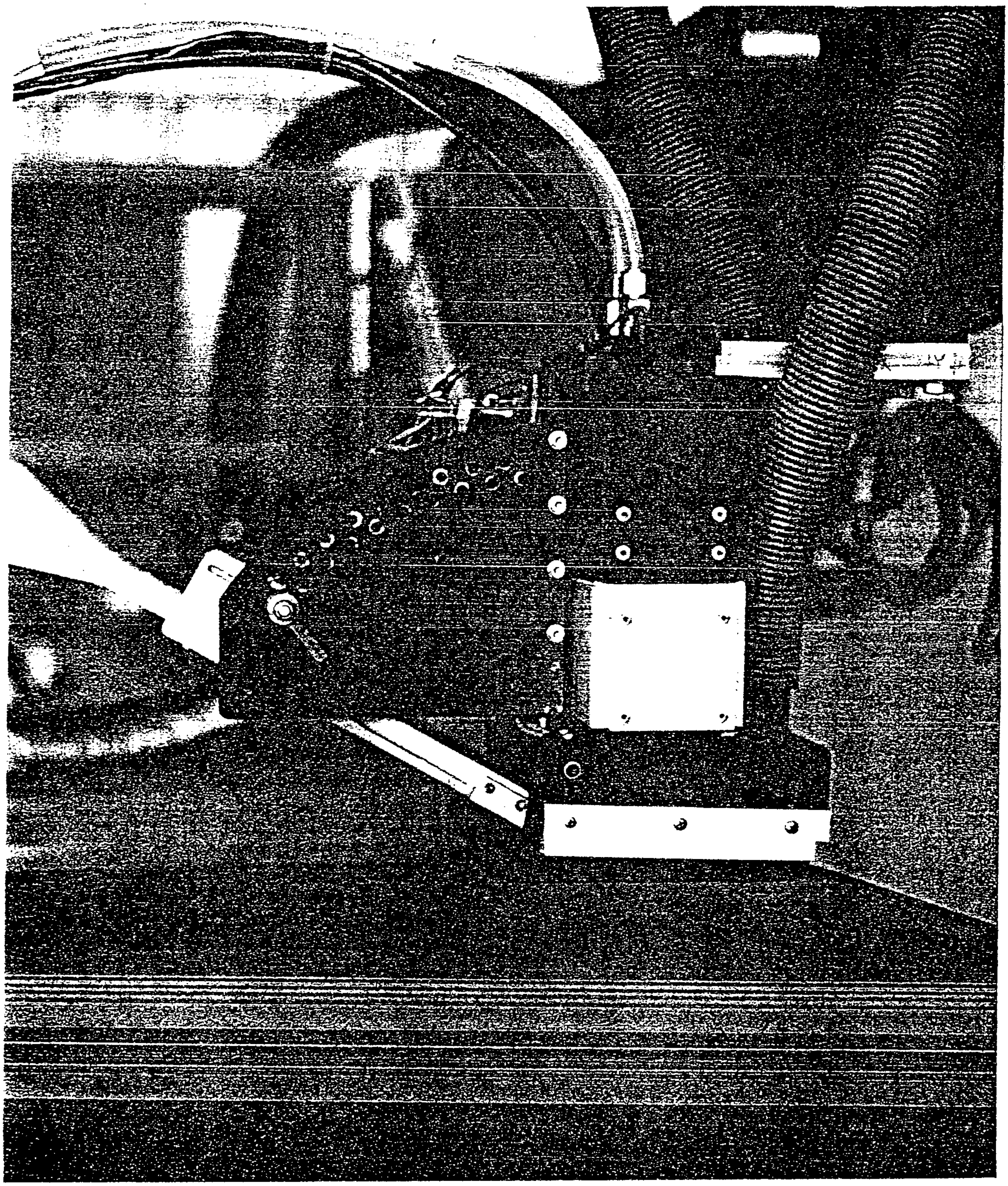


Figure 3. PRAM Stripping Head

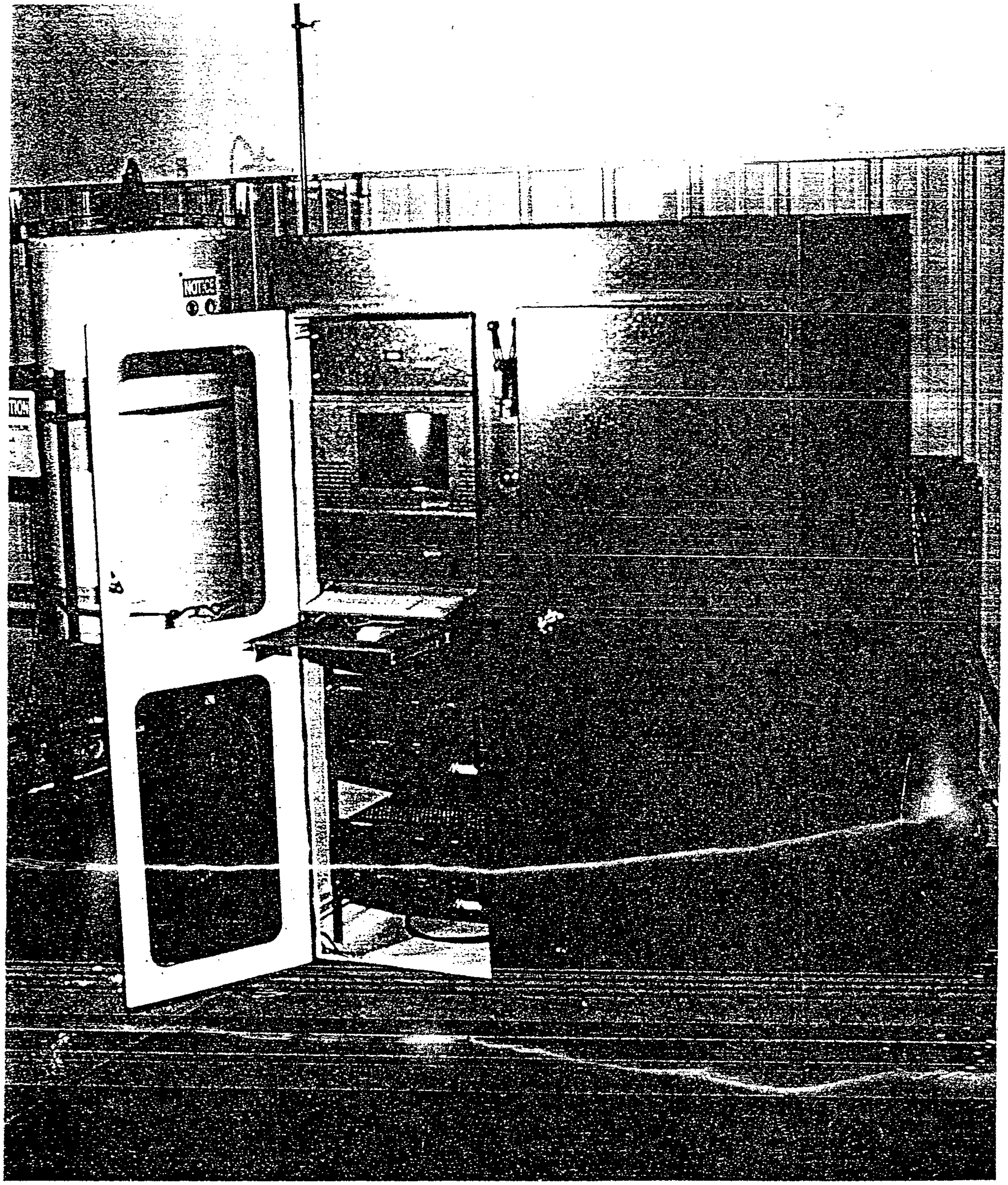


Figure 4. High Voltage Power Supply

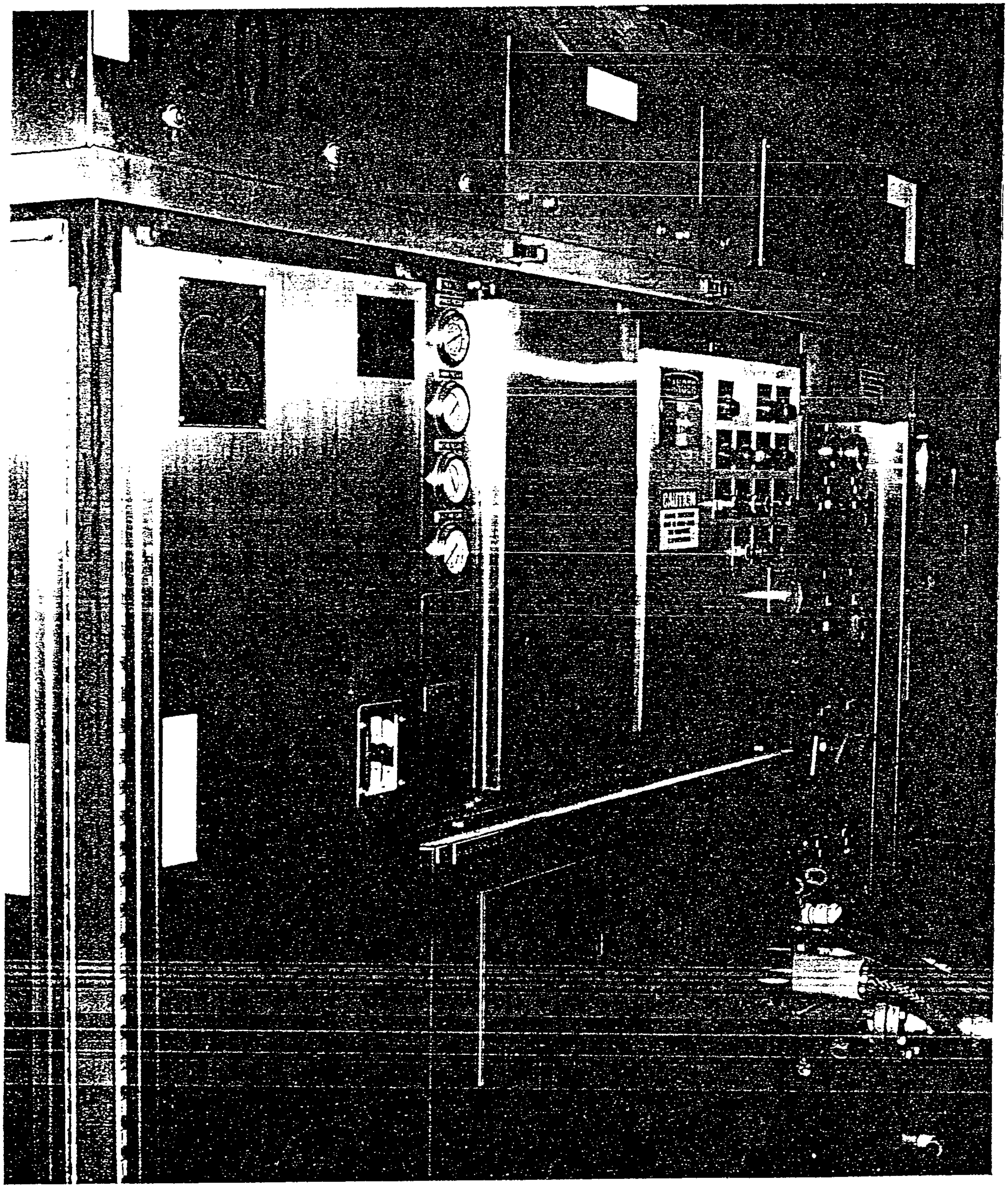


Figure 5. Cold Jet Model 65-200

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	L	B	C	D	E	F	G	H	I	J	K	L	M
1				PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP
2	(PROCESS)												
3	DEPAINT	MANPOWER	STRIP RATE	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	DISPOSAL COS	A/C WASH	A/C WASH
4	AREA SQ FT	COST $/HR	SQ FT/MIN/NOZ	MANHOURS	NO. OF PERS	MANPOWER $	GAL OF SOAP	SOAP $/GAL	TOT SOAP $	WASTE GAL	DOL /GAL	DISPOSAL $ TO	FLOW TIME
5	DATA	DATA	DATA	DATA	DATA	COMPUTED	DATA	DATA	COMPUTED	DATA	DATA	COMPUTED	COMPUTED
6													
7	(CHEMI[illegible])												
8	2,000.0	60.00	N/A	16.00	4.00	960.00	20.00	2.21	44.20	2,000.00	0.01	22.00	4.00
9	9,000.0	60.00	N/A	32.00	9.00	1,920.00	60.00	2.21	132.60	6,000.00	0.01	66.00	4.00
10	18,000.0	60.00	N/A	60.00	10.00	3,600.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00
11	(PMB)												
12	2,000.00	60.00	1.00	16.00	4.00	960.00	20.00	2.21	44.20	2,000.00	0.01	22.00	4.00
13	9,000.00	60.00	1.50	32.00	8.00	1,600.00	60.00	2.21	600.00	6,000.00	0.01	66.00	4.00
14	18,000.00	60.00	1.50	60.00	10.00	3,600.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00
15	(ROBOT PMB)												
16	2,000.00	60.00	1.00	16.00	4.00	960.00	20.00	2.21	44.20	2,000.00	0.01	22.00	4.00
17	9,000.00	60.00	1.50	32.00	8.00	1,600.00	60.00	2.21	600.00	6,000.00	0.01	66.00	4.00
18	18,000.00	60.00	1.50	60.00	10.00	3,600.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00
19	(WHEAT)												
20	2,000.00	60.00	0.70	16.00	[illegible]	960.00	20.00	2.21	44.20	2,000.00	0.01	22.00	4.00
21	9,000.00	60.00	1.00	32.00	[illegible]	1,600.00	60.00	2.21	600.00	6,000.00	0.01	66.00	4.00
22	18,000.00	60.00	1.00	60.00	10.00	3,600.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00
23	(CO2/N2)												
24	2,000.00	60.00	0.49	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
25	9,000.00	60.00	0.89	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
26	18,000.00	60.00	0.89	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
27	(MANIP CO2/N2)												
28	2,000.00	60.00	0.49	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
29	9,000.00	60.00	0.89	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
30	18,000.00	60.00	0.89	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
31	(ROBOT CO2/N2)												
32	2,000.00	60.00	0.49	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
33	9,000.00	60.00	0.89	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
34	18,000.00	[illegible]	0.89	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
35	(MANIP FLASH)												
36	2,000.00	[illegible]	1.50	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
37	9,000.00	[illegible]	3.00	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
38	18,000.00	60.00	3.00	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
39	(ROBOT FLASH)												
40	2,000.00	60.00	1.50	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
41	9,000.00	60.00	3.00	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
42	18,000.00	60.00	3.00	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
43	(ROBOT HI H2O)												
44	2,000.00	60.00	1.25	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
45	9,000.00	60.00	2.60	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
46	18,000.00	60.00	2.60	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
47	(MED PRES H2O)												
48	2,000.00	60.00	0.05	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
49	9,000.00	60.00	2.00	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
50	18,000.00	60.00	2.00	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
51	(MED H2O BICARB)												
52	2,000.00	[illegible]	1.00	0.00	4.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
53	9,000.00	[illegible]	2.00	0.00	8.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00
54	18,000.00	60.00	2.00	0.00	10.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00

[MATOP6.WK3]A

As Of: 2/4/93

app 2

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z *
1	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	PRE-STRIP	STRIPPING	STRIPPING	STRIPPING
2		COMPONENT	COMPONENT	COMPONENT	COMPONENT						OPERATION	OPERATION	OPERATION
3	A/C WASH	REMOVAL	REMOVAL	REMOVAL	REMOVAL	MASK/PLUG	MASK/PLUG	MASK/PLUG	MASK/PLUG	MASK/PLUG	NO. NOZ	PELLETS	MEDIA CONV.
4	TOT COST $	MANHOUR	NO. OF PERS	ANPOW COST	FLOW TIME	MANHOURS	NO. OF PERS	MANPOW $	FLOW TIME	MATERIAL $		LB/HR/NOZ	
5	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	COMPUTED	DATA	DATA	DATA
6													
7													
8	1,026.20	0.00	0.00	0.00	0.00	96.00	4.00	5,760.00	24.00	604.05	N/A	N/A	N/A
9	2,118.60	0.00	0.00	0.00	0.00	240.00	10.00	14,400.00	24.00	914.10	N/A	N/A	N/A
10	3,964.10	0.00	0.00	0.00	0.00	288.00	12.00	17,280.00	24.00	1,424.76	N/A	N/A	N/A
11													
12	1,026.20	40.00	4.00	2,400.00	10.00	80.00	4.00	4,800.00	20.00	1,000.00	4.00	450.00	1.00
13	2,266.00	120.00	8.00	7,200.00	15.00	160.00	8.00	9,600.00	20.00	2,000.00	8.00	450.00	1.00
14	3,964.10	120.00	8.00	7,200.00	15.00	160.00	8.00	9,600.00	20.00	2,000.00	20.00	450.00	1.00
15													
16	1,026.20	40.00	4.00	2,400.00	10.00	80.00	4.00	4,800.00	20.00	1,000.00	4.00	450.00	1.00
17	2,266.00	120.00	8.00	7,200.00	15.00	160.00	8.00	9,600.00	20.00	2,000.00	6.00	450.00	1.00
18	3,964.10	120.00	8.00	7,200.00	15.00	160.00	8.00	9,600.00	20.00	2,000.00	16.00	450.00	1.00
19													
20	1,026.20	40.00	4.00	2,400.00	10.00	100.00	4.00	6,000.00	25.00	1,000.00	6.00	450.00	1.00
21	2,266.00	120.00	8.00	7,200.00	15.00	180.00	8.00	10,800.00	22.50	2,000.00	12.00	450.00	1.00
22	3,964.10	120.00	8.00	7,200.00	15.00	180.00	8.00	10,800.00	22.50	2,000.00	24.00	450.00	1.00
23													
24	0.00	40.00	4.00	2,400.00	10.00	30.00	4.00	1,800.00	7.50	300.00	6.00	450.00	2.00
25	0.00	120.00	8.00	7,200.00	15.00	60.00	8.00	3,600.00	7.50	1,200.00	8.00	450.00	2.00
26	0.00	120.00	8.00	7,200.00	15.00	60.00	8.00	3,600.00	7.50	1,200.00	16.00	450.00	2.00
27													
28	0.00	40.00	4.00	2,400.00	10.00	30.00	4.00	1,800.00	7.50	300.00	4.00	600.00	2.00
29	0.00	120.00	8.00	7,200.00	15.00	60.00	8.00	3,600.00	7.50	1,200.00	4.00	600.00	2.00
30	0.00	120.00	8.00	7,200.00	15.00	60.00	8.00	3,600.00	7.50	1,200.00	8.00	600.00	2.00
31													
32	0.00	40.00	4.00	2,400.00	10.00	30.00	4.00	1,800.00	7.50	300.00	4.00	600.00	2.00
33	0.00	120.00	8.00	7,200.00	15.00	60.00	8.00	3,600.00	7.50	1,200.00	4.00	600.00	2.00
34	0.00	120.00	8.00	7,200.00	15.00	60.00	8.00	3,600.00	7.50	1,200.00	8.00	600.00	2.00
35													
36	0.00	20.00	4.00	1,200.00	5.00	30.00	4.00	1,800.00	7.50	300.00	2.00	1,000.00	2.00
37	0.00	40.00	8.00	2,400.00	5.00	60.00	8.00	3,600.00	7.50	1,200.00	2.00	1,000.00	2.00
38	0.00	40.00	8.00	2,400.00	5.00	60.00	8.00	3,600.00	7.50	1,200.00	3.00	1,000.00	2.00
39													
40	0.00	20.00	4.00	1,200.00	5.00	30.00	4.00	1,800.00	7.50	300.00	1.00	1,000.00	2.00
41	0.00	40.00	8.00	2,400.00	5.00	60.00	8.00	3,600.00	7.50	1,200.00	2.00	1,000.00	2.00
42	0.00	40.00	8.00	2,400.00	5.00	60.00	8.00	3,600.00	7.50	1,200.00	2.00	1,000.00	2.00
43													
44	0.00	40.00	4.00	2,400.00	10.00	30.00	4.00	1,800.00	7.50	300.00	1.00	480.00	1.00
45	0.00	80.00	8.00	4,800.00	10.00	60.00	8.00	3,600.00	7.50	1,200.00	2.00	480.00	1.00
46	0.00	80.00	8.00	4,800.00	10.00	60.00	8.00	3,600.00	7.50	1,200.00	3.00	480.00	1.00
47													
48	0.00	40.00	4.00	2,400.00	10.00	50.00	4.00	3,000.00	12.50	300.00	4.00	600.00	1.00
49	0.00	80.00	8.00	4,800.00	10.00	100.00	8.00	6,000.00	12.50	1,200.00	3.00	600.00	1.00
50	0.00	80.00	8.00	4,800.00	10.00	100.00	8.00	6,000.00	12.50	1,200.00	8.00	600.00	1.00
51													
52	0.00	40.00	4.00	2,400.00	10.00	100.00	4.00	6,000.00	25.00	300.00	3.00	1,000.00	1.00
53	0.00	80.00	8.00	4,800.00	10.00	180.00	8.00	10,800.00	22.50	1,200.00	4.00	1,000.00	1.00
54	0.00	80.00	8.00	4,800.00	10.00	180.00	8.00	10,800.00	22.50	1,200.00	8.00	1,000.00	1.00

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM *
1	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING
2	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION
3	PEL REQ'D	FRACT OF	FRACT OF TIME	NET STRIP RAT	GAL OR # OF	FRACT OF	MAKEUP MEDIA	COST OF MEDIA	MAKEUP MEDIA	POUNDS MEDIA	DISPOSAL COS	DISPOSAL	POUNDS OF
4	LB/HR/NOZ	TIME WORKING	EFFECTIVE	SQ FT/MIN/NOZ	MEDIA PER A/C	ED DISCARDE	REQ'D # OR GA	DOL/GAL OR #	COST $	EQ'N DISPOSA	DOL/LB OR GAL	COST $	PAINT PER A/C
5	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	DATA	COMPUTED	DATA	COMPUTED	COMPUTED	DATA	COMPUTED	DATA
6					(DATA FOR CHEM)								
7													
8	N/A	N/A	N/A	N/A	660.00	1.00	660.00	4.000	2,640.00	6,600.00	2.00	13,200.00	240.00
9	N/A	N/A	N/A	N/A	1,100.00	1.00	1,100.00	4.000	4,400.00	11,000.00	2.00	22,000.00	500.00
10	N/A	N/A	N/A	N/A	1,650.00	1.00	1,650.00	4.000	6,600.00	16,500.00	2.00	33,000.00	1,000.00
11													
12	450.00	0.50	0.80	0.40	18,750.00	0.10	1,875.00	1.650	3,093.75	1,875.00	0.27	506.25	240.00
13	450.00	0.50	0.80	0.60	56,250.00	0.10	5,625.00	1.650	9,281.25	5,625.00	0.27	1,518.75	600.00
14	450.00	0.50	0.80	0.60	112,500.00	0.10	11,250.00	1.650	18,562.50	11,250.00	0.27	3,037.50	1,200.00
15													
16	450.00	0.80	0.80	0.64	18,750.00	0.10	1,875.00	1.650	3,093.75	1,875.00	0.27	506.25	240.00
17	450.00	0.80	0.80	0.96	56,250.00	0.10	5,625.00	1.650	9,281.25	5,625.00	0.27	1,518.75	600.00
18	450.00	0.80	0.80	0.96	112,500.00	0.10	11,250.00	1.650	18,562.50	11,250.00	0.27	3,037.50	1,200.00
19													
20	450.00	0.50	0.80	0.28	26,785.71	0.05	1,339.29	1.650	2,209.82	1,339.29	0.27	361.61	240.00
21	450.00	0.50	0.80	0.40	84,375.00	0.05	4,218.75	1.650	6,960.94	4,218.75	0.27	1,139.06	600.00
22	450.00	0.50	0.80	0.40	168,750.00	0.05	8,437.50	1.650	13,921.88	8,437.50	0.27	2,278.13	1,200.00
23													
24	900.00	0.50	0.80	0.19	77,002.05	1.00	77,002.05	0.030	2,310.06	77,002.05	0.00	0.00	240.00
25	900.00	0.50	0.80	0.36	189,606.74	1.00	189,606.74	0.030	5,688.20	189,606.74	0.00	0.00	600.00
26	900.00	0.50	0.80	0.36	379,213.48	1.00	379,213.48	0.030	11,376.40	379,213.48	0.00	0.00	1,200.00
27													
28	1,200.00	0.80	0.90	0.35	91,261.69	1.00	91,261.69	0.030	2,737.85	91,261.69	0.00	0.00	240.00
29	1,200.00	0.80	0.90	0.64	224,719.10	1.00	224,719.10	0.030	6,741.57	224,719.10	0.00	0.00	1,200.00
30	1,200.00	0.80	0.90	0.64	449,438.20	1.00	449,438.20	0.030	13,483.15	449,438.20	0.00	0.00	1,200.00
31													
32	1,200.00	0.80	0.95	0.37	86,458.45	1.00	86,458.45	0.030	2,593.75	86,458.45	0.00	0.00	240.00
33	1,200.00	0.80	0.95	0.68	212,891.78	1.00	212,891.78	0.030	6,386.75	212,891.78	0.00	0.00	600.00
34	1,200.00	0.80	0.95	0.68	425,783.56	1.00	425,783.56	0.030	12,773.51	425,783.56	0.00	0.00	1,200.00
35													
36	2,000.00	0.80	0.90	1.08	49,382.72	1.00	49,382.72	0.030	1,481.48	49,382.72	0.00	0.00	240.00
37	2,000.00	0.80	0.90	2.16	111,111.11	1.00	111,111.11	0.030	3,333.33	111,111.11	0.00	0.00	1,200.00
38	2,000.00	0.80	0.90	2.16	222,222.22	1.00	222,222.22	0.030	6,666.67	222,222.22	0.00	0.00	1,200.00
39													
40	2,000.00	0.80	0.95	1.14	46,783.63	1.00	46,783.63	0.030	1,403.51	46,783.63	0.00	0.00	240.00
41	2,000.00	0.80	0.95	2.28	105,263.16	1.00	105,263.16	0.030	3,157.89	105,263.16	0.00	0.00	600.00
42	2,000.00	0.80	0.95	2.28	210,526.32	1.00	210,526.32	0.030	6,315.79	210,526.32	0.00	0.00	1,200.00
43													
44	480.00	0.80	0.95	0.95	13,473.68	1.00	13,473.68	0.001	13.47	13,473.68	0.01	148.21	240.00
45	480.00	0.80	0.95	1.98	29,149.80	1.00	29,149.80	0.001	29.15	29,149.80	0.01	320.65	600.00
46	480.00	0.80	0.95	1.98	58,299.60	1.00	58,299.60	0.001	58.30	58,299.60	0.01	641.30	1,200.00
47													
48	1,000.00	0.50	0.80	0.02	833,333.33	1.00	833,333.33	0.001	833.33	833,333.33	0.01	9,166.67	240.00
49	1,000.00	0.50	0.80	0.80	93,750.00	1.00	93,750.00	0.001	93.75	93,750.00	0.01	1,031.25	600.00
50	1,000.00	0.50	0.80	0.80	187,500.00	1.00	[illegible]	0.001	187.50	187,500.00	0.01	2,062.50	1,200.00
51													
52	1,000.00	0.50	0.80	0.40	41,666.67	1.00	41,[illegible]7	0.001	41.67	41,666.67	0.01	458.33	240.00
53	1,000.00	0.50	0.80	0.80	93,750.00	1.00	93,750.00	0.001	93.75	93,750.00	0.01	1,031.25	600.00
54	1,000.00	0.50	0.80	0.80	187,500.00	1.00	187,500.00	0.001	187.50	187,500.00	0.01	2,062.50	1,200.00

[MATOP6.WK3]A

As Of: 2/4/93

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
1	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING	STRIPPING
2	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION	OPERATION
3	PAINT DISPO	PAINT DISPO	AIR VOLUME	AIR PRESSURE	HORSE POWER	COMP AIR	OTHER EQUIP	KILOWATTS	ELECTRICITY	TOT ELECT	STRIP FLOW	STRIP	STRIP
4	COST $/#	TOT COST	CUFT/MIN/NOZ	PSI	PER NOZ/HR	ILOWATS/NOZ/H	ILOWATS/NOZ/H	TOTAL	COST $/KW	COST	TIME HR	MANHOURS HR	MANPOW $
5	DATA	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	DATA	COMPUTED	DATA	COMPUTED	COMPUTED	COMPUTED	COMPUTED
6											(DAT 4 CHEM)	(DAT 4 CHEM)	
7													
8	2.00	480.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	120.00	480.00	28,800.00
9	2.00	1,000.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	72.00	300.00	18,000.00
10	2.00	2,000.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	80.00	410.00	24,600.00
11													
12	0.27	64.80	220.00	64.70	25.97	19.37		806.92	0.07	52.45	20.83	83.33	5,000.00
13	0.27	162.00	220.00	64.70	25.97	19.37		2,420.76	0.07	157.35	31.25	250.00	15,000.00
14	0.27	324.00	220.00	64.70	25.97	19.37		4,841.52	0.07	314.70	25.00	500.00	30,000.00
15													
16	0.27	64.80	220.00	64.70	25.97	19.37		806.92	0.07	52.45	13.02	26.04	1,562.50
17	0.27	162.00	220.00	64.70	25.97	19.37		2,420.76	0.07	157.35	26.04	78.13	4,687.50
18	0.27	324.00	220.00	64.70	25.97	19.37		4,841.52	0.07	314.70	19.53	156.25	9,375.00
19													
20	0.27	64.80	220.00	40.00	16.32	12.17		724.53	0.07	47.09	19.84	119.05	7,142.86
21	0.27	162.00	220.00	40.00	16.32	12.17		2,282.27	0.07	148.35	31.25	375.00	22,500.00
22	0.27	324.00	220.00	40.00	16.32	12.17		4,564.54	0.07	296.69	31.25	750.00	45,000.00
23													
24	0.27	64.80	300.00	314.70	93.81	69.95	7.70	6,643.85	0.07	431.85	28.52	342.23	20,533.88
25	0.27	162.00	300.00	314.70	93.81	69.95	7.70	16,359.54	0.07	1,063.37	52.67	842.70	50,561.80
26	0.27	324.00	300.00	314.70	93.81	69.95	7.70	32,719.09	0.07	2,126.74	52.67	1,685.39	101,123.60
27													
28	0.27	64.80	300.00	314.70	93.81	69.95	7.70	5,905.64	0.07	383.87	23.77	47.53	2,851.93
29	0.27	324.00	300.00	314.70	93.81	69.95	7.70	14,541.82	0.07	945.22	58.52	117.04	7,022.47
30	0.27	324.00	300.00	314.70	93.81	69.95	7.70	29,083.63	0.07	1,890.44	58.52	234.08	14,044.94
31													
32	0.27	64.80	300.00	314.70	93.81	69.95	7.70	5,594.82	0.07	363.66	22.52	45.03	2,701.83
33	0.27	162.00	600.00	314.70	187.62	139.91	7.70	26,186.86	0.07	1,702.15	55.44	110.88	6,652.87
34	0.27	324.00	600.00	314.70	187.62	139.91	7.70	52,373.72	0.07	3,404.29	55.44	221.76	13,305.74
35													
36	0.27	64.80	300.00	180.00	70.14	52.31	15.40	1,671.76	0.07	108.66	15.43	30.86	1,851.85
37	0.27	324.00	300.00	180.00	70.14	52.31	15.40	3,761.46	0.07	244.50	34.72	69.44	4,166.67
38	0.27	324.00	300.00	180.00	70.14	52.31	15.40	7,522.92	0.07	488.99	46.30	138.89	8,333.33
39													
40	0.27	64.80	300.00	180.00	70.14	52.31	15.40	1,583.77	0.07	102.95	29.24	29.24	1,754.39
41	0.27	162.00	600.00	180.00	140.29	104.61	15.40	6,316.46	0.07	410.57	32.89	65.79	3,947.37
42	0.27	324.00	600.00	180.00	140.29	104.61	15.40	12,632.91	0.07	821.14	65.79	131.58	7,894.74
43													
44	0.27	64.80	0.00	80.00	0.00	0.00	30.00	842.11	0.07	54.74	35.09	35.09	2,105.26
45	0.27	162.00	0.00	80.00	0.00	0.00	30.00	1,821.86	0.07	118.42	37.96	75.91	4,554.66
46	0.27	324.00	0.00	80.00	0.00	0.00	30.00	3,643.72	0.07	236.84	50.61	151.82	9,109.31
47													
48	0.27	64.80	1.00	80.00	0.14	0.00	15.40	12,833.33	0.07	834.17	416.67	1,666.67	100,000.00
49	0.27	162.00	1.00	80.00	0.14	0.10	15.40	1,453.49	0.07	94.48	62.50	187.50	11,250.00
50	0.27	324.00	1.00	80.00	0.14	0.10	15.40	2,906.99	0.07	188.95	46.88	375.00	22,500.00
51													
52	0.27	64.80	1.00	80.00	0.14	0.00	15.40	641.67	0.07	41.71	27.78	83.33	5,000.00
53	0.27	162.00	1.00	80.00	0.14	0.10	15.40	1,453.49	0.07	94.48	46.88	187.50	11,250.00
54	0.27	324.00	1.00	80.00	0.14	0.10	15.40	2,906.99	0.07	188.95	46.88	375.00	22,500.00

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM
1	STRIPPING	STRIPPING	STRIPPING	STRIPPING	POST	POST	POST	POST	POST	POST	POST	POST	POST
2	OPERATION	OPERATION	OPERATION	OPERATION	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP
3	ER CONSUMABLES			CONSUMABLES	DEMASK	DEMASK	DEMASK	DEMASK	SEAM STRIP	SEAM STRIP	SEAM STRIP	SEAM STRIP	A/C WASH
4	(DESCRIPTION)			$/PLANE	MANHOURS	MANPOW $	NO PERSONS	TIME HR	MANHOUR	NO. OF PERS	ANPOW COST	FLOW TIME	MANHOURS
5	DATA	DATA	COMPUTED	COMPUTED	DATA	COMPUTED	DATA	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	DATA
6													
7													
8	NONE			0.00	16.00	960.00	4.00	4.00	40.00	4.00	2,400.00	10.00	16.00
9				0.00	80.00	4,800.00	10.00	8.00	120.00	8.00	7,200.00	15.00	32.00
10				0.00	120.00	7,200.00	12.00	10.00	120.00	8.00	7,200.00	15.00	60.00
11	NONE												
12				0.00	60.00	3,600.00	4.00	15.00	40.00	4.00	2,400.00	10.00	16.00
13				0.00	120.00	7,200.00	10.00	12.00	120.00	8.00	7,200.00	15.00	32.00
14				0.00	160.00	9,600.00	12.00	13.33	120.00	8.00	7,200.00	15.00	60.00
15													
16				0.00	60.00	3,600.00	4.00	15.00	40.00	4.00	2,400.00	10.00	16.00
17				0.00	120.00	7,200.00	10.00	12.00	120.00	8.00	7,200.00	15.00	32.00
18				0.00	160.00	9,600.00	12.00	13.33	120.00	8.00	7,200.00	15.00	60.00
19													
20				0.00	80.00	4,800.00	4.00	20.00	40.00	4.00	2,400.00	10.00	16.00
21				0.00	160.00	9,600.00	10.00	16.00	120.00	8.00	7,200.00	15.00	32.00
22				0.00	180.00	10,800.00	12.00	15.00	120.00	8.00	7,200.00	15.00	60.00
23	N2 $/GAL	N2 GAL/NOZ/MIN	N2 GAL/PLANE	N2 $/PLANE									
24	0.29	1.90	9,753.59	2,828.54	16.00	960.00	4.00	4.00	10.00	4.00	600.00	2.50	0.00
25	0.29	1.90	24,016.05	6,964.89	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
26	0.29	1.90	48,033.71	13,929.78	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
27	N2 $/GAL	N2 GAL/NOZ/MIN	N2 GAL/PLANE	N2 $/PLANE									
28	0.29	1.90	8,669.86	2,514.26	16.00	960.00	4.00	4.00	10.00	4.00	600.00	2.50	0.00
29	0.29	1.90	21,348.31	6,191.01	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
30	0.29	1.90	42,696.63	12,382.02	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
31	N2 $/GAL	N2 GAL/NOZ/MIN	N2 GAL/PLANE	N2 $/PLANE									
32	0.29	1.90	8,213.55	2,381.93	16.00	960.00	4.00	4.00	10.00	4.00	600.00	2.50	0.00
33	0.29	1.90	20,224.72	5,865.17	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
34	0.29	1.90	40,449.44	11,730.34	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
35	AMP COST $/LAM	LAMP LIFE HOURS	LAMPS/PLANE	$/PLANE									
36	650.00	80.00	0.31	200.62	16.00	960.00	4.00	4.00	20.00	4.00	1,200.00	5.00	0.00
37	650.00	80.00	0.69	451.39	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
38	650.00	80.00	1.39	902.78	60.00	3,600.00	8.00	7.50	40.00	8.00	2,400.00	5.00	0.00
39	AMP COST $/LAM	LAMP LIFE HOURS	LAMPS/PLANE	$/PLANE									
40	650.00	80.00	0.29	190.06	16.00	960.00	4.00	4.00	20.00	4.00	1,200.00	5.00	0.00
41	650.00	80.00	0.66	427.63	60.00	3,600.00	10.00	6.00	40.00	8.00	2,400.00	5.00	0.00
42	650.00	80.00	1.32	855.26	60.00	3,600.00	12.00	5.00	40.00	8.00	2,400.00	5.00	0.00
43													
44				0.00	16.00	960.00	4.00	4.00	40.00	4.00	2,400.00	10.00	0.00
45				0.00	60.00	3,600.00	8.00	7.50	80.00	8.00	4,800.00	10.00	0.00
46				0.00	60.00	3,600.00	8.00	7.50	80.00	8.00	4,800.00	10.00	0.00
47													
48				0.00	50.00	3,000.00	4.00	12.50	40.00	4.00	2,400.00	10.00	0.00
49				0.00	100.00	6,000.00	8.00	12.50	80.00	8.00	4,800.00	10.00	0.00
50				0.00	100.00	6,000.00	8.00	12.50	80.00	8.00	4,800.00	10.00	0.00
51	BICARB $/LBS	LBS/PLANE		$/PLANE									
52	0.37	3,750.00		1,387.50	100.00	6,000.00	4.00	25.00	40.00	4.00	2,400.00	10.00	0.00
53	0.37	8,4[illegible]0		3,121.88	180.00	10,800.00	8.00	22.50	80.00	8.00	4,800.00	10.00	0.00
54	0.37	16,[illegible]0		6,243.75	180.00	10,800.00	8.00	22.50	80.00	8.00	4,800.00	10.00	0.00

{MATOP6.WK3}A

As Of: 2/4/93

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ *
1	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST
2	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP
3	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	A/C WASH	ETCH	ETCH	ETCH
4	NO. OF PERS	MANPOWER $	GAL OF SOAP	SOAP $/GAL	TOT SOAP $	WASTE GAL	DOL /GAL	DISPOS $ TOT	FLOW TIME	TOT COST $	MANHOURS	NO. OF PERS	MANPOWER $
5	DATA	COMPUTED	DATA	DATA	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	COMPUTED	DATA	DATA	COMPUTED
6													
7													
8	4.00	960.00	20.00	2.21	44.20	2,000.00	0.01	22.00	4.00	1,026.20	8.00	4.00	480.00
9	8.00	1,920.00	60.00	2.21	132.60	6,000.00	0.01	66.00	4.00	2,118.60	32.00	8.00	1,920.00
10	10.00	3,600.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00	3,964.10	60.00	10.00	3,600.00
11													
12	4.00	800.00	20.00	2.21	200.00	2,000.00	0.01	22.00	4.00	1,022.00	8.00	4.00	480.00
13	8.00	1,600.00	60.00	2.21	600.00	6,000.00	0.01	66.00	4.00	2,266.00	32.00	8.00	1,920.00
14	10.00	900.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00	1,264.10	60.00	10.00	3,600.00
15													
16	4.00	800.00	20.00	2.21	200.00	2,000.00	0.01	22.00	4.00	1,022.00	8.00	4.00	480.00
17	8.00	1,600.00	60.00	2.21	600.00	6,000.00	0.01	66.00	4.00	2,266.00	32.00	8.00	1,920.00
18	10.00	900.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00	1,264.10	60.00	10.00	3,600.00
19													
20	4.00	800.00	20.00	2.21	200.00	2,000.00	0.01	22.00	4.00	1,022.00	8.00	4.00	480.00
21	8.00	1,600.00	60.00	2.21	600.00	6,000.00	0.01	66.00	4.00	2,266.00	32.00	8.00	1,920.00
22	10.00	900.00	110.00	2.21	243.10	11,000.00	0.01	121.00	6.00	1,264.10	60.00	10.00	3,600.00
23													
24	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	8.00	4.00	480.00
25	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	32.00	8.00	1,920.00
26	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	60.00	10.00	3,600.00
27													
28	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	8.00	4.00	480.00
29	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	32.00	10.00	1,920.00
30	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	60.00	10.00	3,600.00
31													
32	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	8.00	4.00	480.00
33	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	32.00	8.00	1,920.00
34	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	60.00	10.00	3,600.00
35													
36	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	0.00	4.00	0.00
37	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	0.00	10.00	0.00
38	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	0.00	10.00	0.00
39													
40	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	0.00	4.00	0.00
41	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	0.00	8.00	0.00
42	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	0.00	10.00	0.00
43													
44	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	8.00	4.00	480.00
45	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	32.00	8.00	1,920.00
46	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	60.00	10.00	3,600.00
47													
48	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	8.00	4.00	480.00
49	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	32.00	8.00	1,920.00
50	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	60.00	10.00	3,600.00
51													
52	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	8.00	4.00	480.00
53	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	32.00	8.00	1,920.00
54	0.00	0.00	0.00	2.21	0.00	0.00	0.01	0.00	0.00	0.00	60.00	10.00	3,600.00

[MATOP6.WK3]A

As Of: 2/4/93

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM *
1	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST	POST
2	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP
3	ETCH	ETCH	ETCH	ETCH	ETCH	ETCH	ETCH	ETCH	CONV COAT	CONV COAT	CONV COAT	CONV COAT	CONV COAT
4	GAL OF CHEM	CHEM $/GAL	TOT CHEM $	WASTE GAL	WASTE $/GAL	WASTE TOT $	FLOW TIME	TOT COST $	MANHOURS	NO. OF PERS	MANPOWER $	GAL OF CHEM	CHEM $/GAL
5	DATA	DATA	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	COMPUTED	DATA	DATA	COMPUTED	DATA	DATA
6													
7													
8	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
9	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
10	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
11													
12	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
13	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
14	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
15													
16	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
17	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
18	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
19													
20	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
21	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
22	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
23													
24	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
25	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
26	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
27													
28	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
29	110.00	2.73	300.30	11,000.00	0.01	121.00	3.20	2,341.30	60.00	10.00	3,600.00	200.00	12.63
30	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
31													
32	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
33	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
34	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
35													
36	20.00	2.73	54.60	0.00	0.01	0.00	0.00	54.60	0.00	4.00	0.00	0.00	12.63
37	110.00	2.73	300.30	0.00	0.01	0.00	0.00	300.30	0.00	10.00	0.00	0.00	12.63
38	110.00	2.73	300.30	0.00	0.01	0.00	0.00	300.30	0.00	10.00	0.00	0.00	12.63
39													
40	20.00	2.73	54.60	0.00	0.01	0.00	0.00	54.60	0.00	4.00	0.00	0.00	12.63
41	60.00	2.73	163.80	0.00	0.01	0.00	0.00	163.80	0.00	8.00	0.00	0.00	12.63
42	110.00	2.73	300.30	0.00	0.01	0.00	0.00	300.30	0.00	10.00	0.00	0.00	12.63
43													
44	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
45	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
46	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
47													
48	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
49	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
50	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63
51													
52	20.00	2.73	54.60	2,000.00	0.01	22.00	2.00	556.60	8.00	4.00	480.00	40.00	12.63
53	60.00	2.73	163.80	6,000.00	0.01	66.00	4.00	2,149.80	32.00	8.00	1,920.00	110.00	12.63
54	110.00	2.73	300.30	11,000.00	0.01	121.00	6.00	4,021.30	60.00	10.00	3,600.00	200.00	12.63

[MATOP6.WK3]A

'As Of: 2/4/93

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	CN	CO	CP	CQ	CR	CS	CT	CU	CV	CW	CX	CY	CZ
1	POST	POST	POST	POST	POST	POST	OVERALL	OVERALL	OVERALL	OVERALL	OVERALL	OVERALL	OVERALL
2	STRIP	STRIP	STRIP	STRIP	STRIP	STRIP	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY
3	CONV COAT	CONV COAT	CONV COAT	CONV COAT	CONV COAT	CONV COAT	FLOW TIME	SHIFTS/DAY	FLOW TIME	MATERIAL	MANHOURS	MANPOWER	ASTE DISPOSA
4	TOT CHEM $	WASTE GAL	WASTE $/GAL	ASTE COST TO	FLOW TIME	TOT COST $	HOURS		DAYS	COST		COST	COST
5	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	COMPUTED	COMPUTED	DATA	COMPUTED	COMPUTED	COMPUTED	COMPUTED	COMPUTED
6													
7													
8	505.20	2,000.00	0.01	22.00	2.00	1,007.20	170.00	3.00	7.08	3,892.25	680.00	40,800.00	13,768.00
9	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	135.00	3.00	5.63	7,132.40	868.00	52,080.00	23,319.00
10	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	153.00	3.00	6.38	11,337.26	1,178.00	70,680.00	35,583.00
11													
12	505.20	2,000.00	0.01	22.00	2.00	1,007.20	87.83	3.00	3.66	4,950.20	351.33	21,080.00	659.05
13	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	109.25	3.00	4.55	14,191.70	898.00	53,880.00	1,999.75
14	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	112.33	3.00	4.68	24,189.70	1,300.00	78,000.00	3,944.50
15													
16	505.20	2,000.00	0.01	22.00	2.00	1,007.20	80.02	3.00	3.33	4,950.20	294.04	17,642.50	659.05
17	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	104.04	3.00	4.34	14,191.70	726.13	43,567.50	1,999.75
18	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	106.86	3.00	4.45	24,189.70	956.25	57,375.00	3,944.50
19													
20	505.20	2,000.00	0.01	22.00	2.00	1,007.20	96.84	3.00	4.04	4,060.92	427.05	25,622.86	514.41
21	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	115.75	3.00	4.82	11,862.38	1,083.00	64,980.00	1,620.06
22	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	122.75	3.00	5.11	19,531.07	1,590.00	95,400.00	3,185.13
23													
24	505.20	2,000.00	0.01	22.00	2.00	1,007.20	56.52	3.00	2.35	6,430.25	454.23	27,253.88	108.80
25	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	95.67	3.00	3.99	16,469.56	1,186.70	71,201.80	349.00
26	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	99.67	3.00	4.15	31,459.22	2,085.39	125,123.60	665.00
27													
28	505.20	2,000.00	0.01	22.00	2.00	1,007.20	51.77	3.00	2.16	6,495.78	159.53	9,571.93	108.80
29	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	102.72	3.00	4.28	17,904.10	489.04	29,342.47	665.00
30	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	105.52	3.00	4.40	31,781.90	634.08	38,044.94	665.00
31													
32	505.20	2,000.00	0.01	22.00	2.00	1,007.20	50.52	3.00	2.10	6,199.15	157.03	9,421.83	108.80
33	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	98.44	3.00	4.10	16,707.17	454.88	27,292.87	349.00
34	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	102.44	3.00	4.27	31,934.44	621.76	37,305.74	665.00
35													
36	0.00	0.00	0.01	0.00	0.00	0.00	36.93	3.00	1.54	2,145.36	116.86	7,011.85	64.80
37	0.00	0.00	0.01	0.00	0.00	0.00	59.72	3.00	2.49	5,529.52	269.44	16,166.67	324.00
38	0.00	0.00	0.01	0.00	0.00	0.00	71.30	3.00	2.97	9,558.73	338.89	20,333.33	324.00
39													
40	0.00	0.00	0.01	0.00	0.00	0.00	50.74	3.00	2.11	2,051.11	115.24	6,914.39	64.80
41	0.00	0.00	0.01	0.00	0.00	0.00	56.39	3.00	2.35	5,359.90	265.79	15,947.37	162.00
42	0.00	0.00	0.01	0.00	0.00	0.00	88.29	3.00	3.68	9,492.49	331.58	19,894.74	324.00
43													
44	505.20	2,000.00	0.01	22.00	2.00	1,007.20	70.59	3.00	2.94	928.01	177.09	10,625.26	257.01
45	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	80.96	3.00	3.37	2,900.67	419.91	25,194.66	669.65
46	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	97.61	3.00	4.07	4,321.44	551.82	33,109.31	1,306.30
47													
48	505.20	2,000.00	0.01	22.00	2.00	1,007.20	465.67	3.00	19.40	2,527.30	1,862.67	111,760.00	9,275.47
49	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	115.50	3.00	4.81	2,941.33	611.50	36,690.00	1,380.25
50	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	103.88	3.00	4.33	4,402.75	855.00	51,300.00	2,727.50
51													
52	505.20	2,000.00	0.01	22.00	2.00	1,007.20	101.78	3.00	4.24	2,330.68	379.33	22,760.00	567.13
53	1,389.30	11,000.00	0.01	121.00	4.00	3,430.30	119.88	3.00	4.99	6,063.20	771.50	46,290.00	1,380.25
54	2,526.00	20,000.00	0.01	220.00	6.00	6,346.00	123.88	3.00	5.16	10,646.50	1,015.00	60,900.00	2,727.50

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

(Representative Figures)

	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM *
1	OVERALL	OVERALL	OVERALL	OVERALL	IMPLEMENT	IMPLEMENT	IMPLEMENT	IMPLEMENT	IMPLEMENT	IMPLEMENT	IMPLEMENT	IMPLEMENT	IMPLEMENT
2	SUMMARY	SUMMARY	SUMMARY	SUMMARY	COST	COST	COST	COST	COST	COST	COST	COST	COST
3	TOTAL COST	COST/SQ FT	AIRCRAFT	TOTAL COST	STRIPPING	$/UNIT	TOTAL STRIP	COMPRESSORS	$/COMP	TOTAL COMP	RECOVERY	VENTILATION	ROBOT MANIP
4	PER AIRCRAFT		PER YEAR	PER YEAR	UNITS REQ'D		UNIT COST	REQ'D		COST	SYS COST	COST	COST
5	COMPUTED	COMPUTED	DATA	COMPUTED	DATA	DATA	COMPUTED	DATA	DATA	COMPUTED	COMPUTED	COMPUTED	COMPUTED
6					(CAN COMPUT								
7					FROM # NOZS)								
8	58,460.25	29.23	100.00	5,846,025.00	2.00	3,000.00	6,000.00	0	0	0.00	0		0.00
9	82,531.40	9.17	50.00	4,126,570.00	5.00	3,000.00	15,000.00	0	0	0.00	0		0.00
10	117,600.26	6.53	50.00	5,880,013.00	7.00	3,000.00	21,000.00	0	0	0.00	0		0.00
11													
12	26,689.25	13.34	100.00	2,668,924.98	4.00	70,000.00	280,000.00	2.00	20,000.00	40,000.00	200,000.00	200,000.00	0.00
13	70,071.45	7.79	50.00	3,503,572.47	8.00	70,000.00	560,000.00	4.00	20,000.00	80,000.00	2,025,000.00	900,000.00	0.00
14	106,134.20	5.90	50.00	5,306,709.95	20.00	70,000.00	1,400,000.00	10.00	20,000.00	200,000.00	4,050,000.00	1,800,000.00	0.00
15													
16	23,251.75	11.63	100.00	2,325,174.98	4.00	70,000.00	280,000.00	2.00	20,000.00	40,000.00	200,000.00	200,000.00	1,500,000.00
17	59,758.95	6.64	50.00	2,987,947.47	6.00	70,000.00	420,000.00	3.00	20,000.00	60,000.00	2,025,000.00	900,000.00	3,750,000.00
18	85,509.20	4.75	50.00	4,275,459.95	16.00	70,000.00	1,120,000.00	8.00	20,000.00	160,000.00	4,050,000.00	1,800,000.00	10,000,000.00
19													
20	30,198.18	15.10	100.00	3,019,818.01	6.00	85,000.00	510,000.00	3.00	30,000.00	90,000.00	200,000.00	200,000.00	0.00
21	78,462.45	8.72	50.00	3,923,122.37	12.00	85,000.00	1,020,000.00	6.00	30,000.00	180,000.00	2,025,000.00	900,000.00	0.00
22	118,116.19	6.56	50.00	5,905,809.74	24.00	85,000.00	2,040,000.00	12.00	30,000.00	360,000.00	4,050,000.00	1,800,000.00	0.00
23													
24	33,792.93	16.90	100.00	3,379,293.48	3.00	265,000.00	795,000.00	3.00	125,000.00	375,000.00	100,000.00	0.00	0.00
25	88,020.36	9.78	50.00	4,401,017.90	4.00	265,000.00	1,060,000.00	4.00	125,000.00	500,000.00	450,000.00	0.00	0.00
26	157,247.82	8.74	50.00	7,862,390.80	8.00	265,000.00	2,120,000.00	8.00	125,000.00	1,000,000.00	900,000.00	0.00	0.00
27													
28	16,176.51	8.09	100.00	1,617,650.51	2.00	265,000.00	530,000.00	2.00	125,000.00	250,000.00	100,000.00	0.00	320,000.00
29	47,911.57	5.32	50.00	2,395,578.71	2.00	265,000.00	530,000.00	2.00	125,000.00	250,000.00	450,000.00	0.00	320,000.00
30	70,491.85	3.92	50.00	3,524,592.43	4.00	265,000.00	1,060,000.00	4.00	125,000.00	500,000.00	900,000.00	0.00	640,000.00
31													
32	15,729.77	7.86	100.00	1,572,977.33	2.00	265,000.00	530,000.00	2.00	125,000.00	250,000.00	100,000.00	0.00	3,000,000.00
33	44,349.04	4.93	50.00	2,217,451.80	2.00	265,000.00	530,000.00	2.00	125,000.00	250,000.00	450,000.00	0.00	5,000,000.00
34	69,905.17	3.88	50.00	3,495,258.60	4.00	265,000.00	1,060,000.00	4.00	125,000.00	500,000.00	900,000.00	0.00	10,000,000.00
35													
36	9,222.02	4.61	100.00	922,201.51	2.00	1,500,000.00	3,000,000.00	2.00	100,000.00	200,000.00	36,000.00	0.00	320,000.00
37	22,020.18	2.45	50.00	1,101,009.20	2.00	1,500,000.00	3,000,000.00	2.00	100,000.00	200,000.00	36,000.00	0.00	320,000.00
38	30,216.07	1.68	50.00	1,510,803.39	3.00	1,500,000.00	4,500,000.00	3.00	100,000.00	300,000.00	54,000.00	0.00	480,000.00
39													
40	9,030.30	4.52	100.00	903,029.85	1.00	1,500,000.00	1,500,000.00	1.00	100,000.00	100,000.00	18,000.00	0.00	1,500,000.00
41	21,469.26	2.39	50.00	1,073,463.22	2.00	1,500,000.00	3,000,000.00	2.00	100,000.00	200,000.00	36,000.00	0.00	5,000,000.00
42	29,711.23	1.65	50.00	1,485,561.43	2.00	1,500,000.00	3,000,000.00	2.00	100,000.00	200,000.00	36,000.00	0.00	5,000,000.00
43													
44	11,810.28	5.91	100.00	1,181,028.42	1.00	500,000.00	500,000.00	0.00	0.00	0.00	150,000.00	0.00	1,500,000.00
45	28,764.97	3.20	50.00	1,438,248.72	2.00	500,000.00	1,000,000.00	0.00	0.00	0.00	300,000.00	0.00	5,000,000.00
46	38,737.05	2.15	50.00	1,936,852.45	3.00	500,000.00	1,500,000.00	0.00	0.00	0.00	450,000.00	0.00	7,500,000.00
47													
48	123,562.77	61.78	100.00	12,356,276.67	4.00	45,000.00	180,000.00	1.00	20,000.00	20,000.00	0.00	0.00	0.00
49	41,011.58	4.56	50.00	2,050,578.86	3.00	45,000.00	135,000.00	1.00	20,000.00	20,000.00	0.00	0.00	0.00
50	58,430.25	3.25	50.00	2,921,512.71	8.00	45,000.00	360,000.00	1.00	20,000.00	20,000.00	0.00	0.00	0.00
51													
52	25,657.81	12.83	100.00	2,565,780.83	3.00	45,000.00	135,000.00	1.00	20,000.00	20,000.00	0.00	0.00	0.00
53	53,733.45	5.97	50.00	2,686,672.61	4.00	45,000.00	180,000.00	1.00	20,000.00	20,000.00	0.00	0.00	0.00
54	74,274.00	4.13	50.00	3,713,700.21	8.00	45,000.00	360,000.00	1.00	20,000.00	20,000.00	0.00	0.00	0.00

COST COMPARISON MODEL FOR IMPLEMENTING PAINT STRIPPING TECHNOLOGIES

	DN	DO	DP
1	IMPLEMENT	IMPLEMENT	
2	COST	COST	
3	OTHER COST	PLEMENTATIO	PAYBACK
4	(SPECIFY)	COST $	YEARS
5	DATA	COMPUTED	COMPUTED
6			
7			
8	0.00	6,000.00	N/A
9	0.00	15,000.00	N/A
10	0.00	21,000.00	N/A
11			
12	0.00	520,000.00	0.16
13	0.00	2,665,000.00	4.28
14	0.00	5,650,000.00	9.86
15			
16	0.00	2,020,000.00	0.57
17	0.00	6,255,000.00	5.49
18	0.00	15,330,000.00	9.55
19			
20	0.00	800,000.00	0.28
21	0.00	3,225,000.00	15.85
22	0.00	6,450,000.00	(250.03)
23			
24	0.00	1,270,000.00	0.51
25	0.00	2,010,000.00	(7.32)
26	0.00	4,020,000.00	(2.03)
27			
28	0.00	1,200,000.00	0.28
29	0.00	1,550,000.00	0.90
30	0.00	3,100,000.00	1.32
31			
32	0.00	3,880,000.00	0.91
33	0.00	6,230,000.00	3.26
34	0.00	12,460,000.00	5.22
35			
36	0.00	3,556,000.00	0.72
37	0.00	3,556,000.00	1.18
38	0.00	5,334,000.00	1.22
39			
40	0.00	3,118,000.00	0.63
41	0.00	8,236,000.00	2.70
42	0.00	8,236,000.00	1.87
43			
44	0.00	2,150,000.00	0.46
45	0.00	6,300,000.00	2.34
46	0.00	9,450,000.00	2.40
47			
48	0.00	200,000.00	(0.03)
49	0.00	155,000.00	0.07
50	0.00	380,000.00	0.13
51			
52	0.00	155,000.00	0.05
53	0.00	200,000.00	0.14
54	0.00	380,000.00	0.18

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